

ISSN 0308 - 5589

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD  
DIRECTORATE OF FISHERIES RESEARCH

**FISHERIES RESEARCH  
TECHNICAL REPORT  
No. 64**

The Thames Estuary herring stock

R.J.WOOD

LOWESTOFT, 1981

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Fish. Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft, (64) 21 pp.

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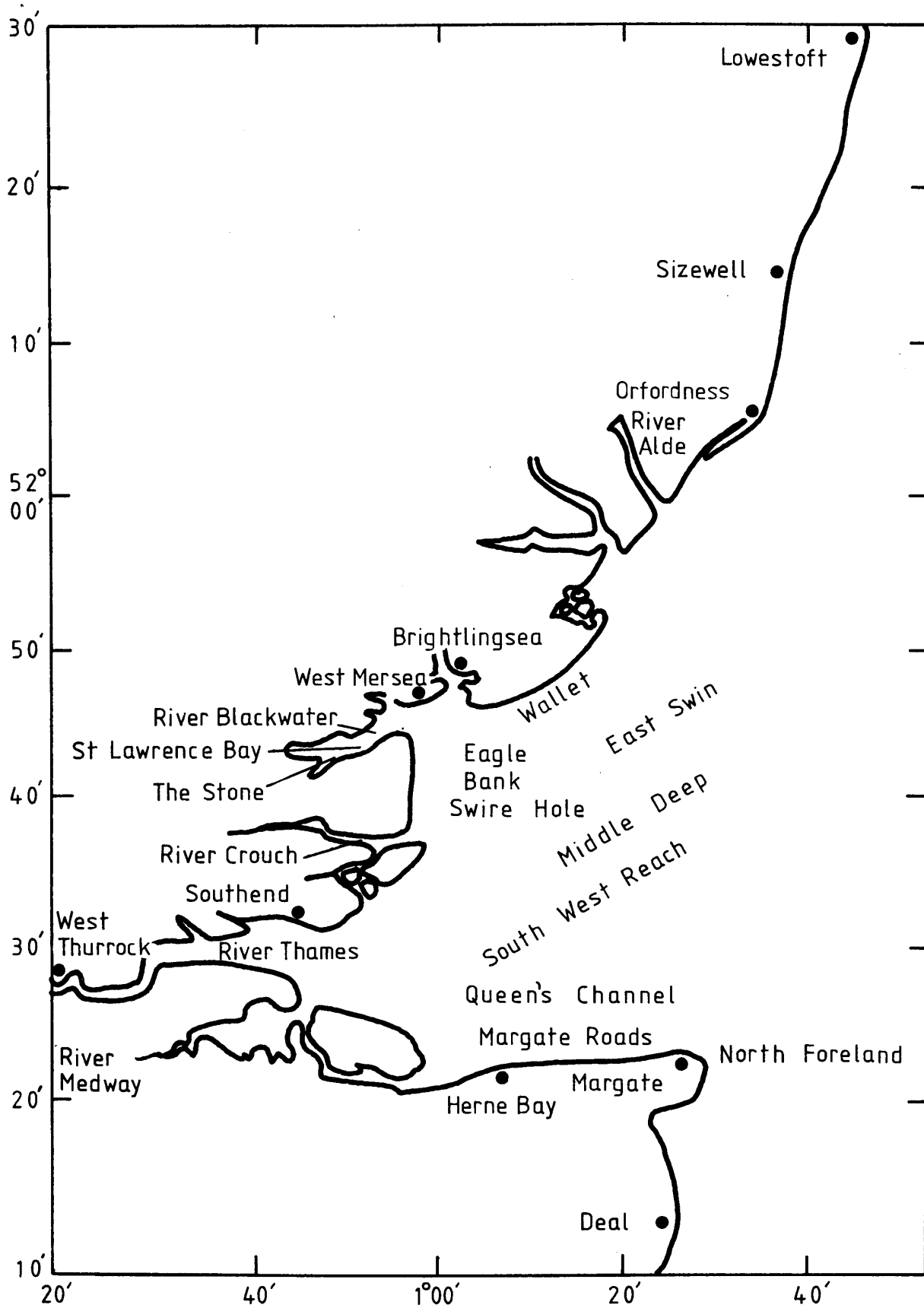


Figure 1 The Thames Estuary, showing places referred to in the text.

## 1. Introduction

Although herring have been caught within the Thames Estuary over a very long period of time, members of the local spring-spawning stock appear to have escaped recognition prior to the early 1800s. Yarrell (1836), after examining herring caught with sprats during winter at the mouth of the Thames, believed that he had identified a second species of British herring which he named *Clupea leachii*, after Dr Leach, a distinguished naturalist of the time, who was reputed to have often declared that our coastline produced a second species of herring distinct from the common Atlantic herring *Clupea harengus* L. Yarrell stated that *Clupea leachii* had 54 vertebrae, a maximum length of not more than 7.5 inches (about 19 cm), an unusually deep belly and spawned in February. Subsequently, these herring were often referred to as Leach's herring.

Murie (1903), in a report on the Sea Fisheries and Fishing Industry of the Thames Estuary, divided the common herring *Clupea harengus* L. into two forms, sea herring and estuarine or river herring. He stated that the latter were shorter in length and relatively deeper bodied than North Sea herring. Regular fisheries for river herring were said to have existed both in the River Medway with seine nets and at the mouth of the River Blackwater with driftnets until about 1860 (Figure 1). Sometimes quite large catches were apparently taken, up to a last (very approximately 12 000 fish or about 1.75 t) of fish per haul. However, by the end of the nineteenth century, according to Murie, only irregular catches of a few individual fish were then being taken. There seems to have been little change in this state of affairs during the first half of the twentieth century.

In fact Hodgson (1929), referring to a sample of spring-spawning herring which had been taken in the River Alde in February 1914, stated that they constituted a small local race not important nor at all widely known. It is believed that a few herring continued to be taken by driftnet in the River Blackwater from time to time and Benham (1977), in an excellent book about the Thames sprat fishery, mentions some catches of herring of up to 300 bushels (approximately 7.5 t) a haul taken at the entrance to the Blackwater by stownetters during the 1930s. These fish were apparently disposed of locally for marinating, but generally it was almost impossible to sell the very small Thames herring in competition with the much better sized and abundant North Sea herring.

In August 1953 some unusually small (4 cm) O-group herring (i.e., fish in their first year of life), having a mean vertebral number of 55.21, were caught by beach seine at Lowestoft (Wood, 1954). Herring of this type had not previously been identified in O-group samples from the East Anglian coast although Hodgson (1929) referred to a sample of very small (5 cm) herring taken at Lowestoft, also by beach seine, in October 1922, on which unfortunately no vertebral counts were made. During October-

December 1953 increasing numbers of herring began to be caught, in what at that time was nothing more than a recreational fishery prosecuted by one or two of the older fishermen within the River Blackwater. Only a few drift-nets were fished by night but catches of several hundred herring began to be taken and one shot in November produced a catch of 700 fish. During the early months of 1954 the sprat trawlers working further out in deeper water also began catching considerable numbers of herring during daylight hauls. Samples from some of the catches were examined at the Fisheries Laboratory, Lowestoft and it was found that the herring were spring spawners with low vertebral counts, the mean being 54.73 (Bolster, 1954). These herring, although mature, were mainly only about 21-23 cm long and were too small to be readily acceptable on the fish markets of Lowestoft and Billingsgate. It was only when the East Anglian herring fishery began to collapse in 1955, with a resultant marked decrease in the supply of North Sea herring, that it became possible to sell Thames herring without the utmost difficulty. From then onwards, however, with an assured market, more fishermen began to participate in the driftnet fishery on a commercial scale. By 1958 the sprat boats, which had converted to midwater pair trawling, also began to take part in the herring fishery when the sprat season had ended in about February-March. By the winter of 1968/69 some 22 trawlers and drifters were engaged in the fishery for Thames herring and the annual catch had reached a level of several hundred tonnes (Table 1).

With the continued decline of both the North Sea stock and other herring stocks in adjacent waters the demand for Thames herring increased and a regular fishery took place for several years during the winter period October-April. The fishery was supported by a number of rich year-classes and in the winter of 1972/73 the recorded catch reached a record 606 t. In 1976 a Management Committee was set up with the twin objectives of rationalizing marketing arrangements and conserving the stock. Unfortunately, a series of poor year-classes then led to a steady decline in the size of stock and made it necessary to impose increasingly severe restrictions on the size of the catches which could be allowed each year. Eventually, the situation became so serious that a complete closure of the fishery had to be imposed in the winter of 1979/80 when the recruiting year-class turned out to be the third weakest ever recorded. Fortunately, the results of a research vessel fishing survey conducted during October 1980 indicated a substantial recovery in the stock and it was possible to advise that the fishery could safely be reopened in the winter of 1980/81.

The following sections of this report are concerned with the biology and life history of the Thames stock, the various assessments which have been made on the state of the stock and the management actions which have been undertaken since the formation of the Management Committee in 1976. In the final section the future of the stock and its fishery are discussed.

**Table 1 Thames Estuary herring fishery: catch in thousands of fish per age group (age in winter rings)**

Fishing season	Age at 1 January													Total	Tonnes
	2	3	4	5	6	7	8	9	10	11	12	13			
1962/63	—	587.65	142.49	355.75	44.80	168.84	115.38	—	—	—	—	—	1 414.91	145.50	
1963/64	—	455.06	297.13	83.35	89.64	52.64	59.37	21.93	—	—	—	—	1 059.12	98.85	
1964/65	31.20	255.49	158.88	52.73	43.47	14.03	14.99	5.59	—	—	—	—	576.38	53.55	
1965/66	45.61	908.29	525.07	181.10	109.11	35.21	11.36	12.14	—	—	—	—	1 827.89	162.25	
1966/67	—	1 690.24	2 021.72	386.54	533.27	48.18	15.55	16.62	—	—	—	—	4 712.12	501.50	
1967/68	14.31	596.52	1 110.14	510.21	78.75	108.65	23.08	4.71	—	—	—	—	2 446.37	277.25	
1968/69	9.17	88.06	535.25	660.28	184.54	24.79	26.25	8.79	1.14	—	—	—	1 538.27	201.70	
1969/70	14.50	60.39	122.90	661.49	718.37	364.44	63.51	67.26	10.63	1.38	—	—	2 084.87	298.80	
1970/71	24.46	1 072.05	5.82	10.37	51.02	59.99	14.44	2.91	3.26	—	—	—	1 244.12	109.50	
1971/72	—	282.00	969.94	3.66	13.32	33.95	22.99	17.71	0.44	—	—	—	1 344.02	163.90	
1972/73	—	1 137.01	1 384.39	2 121.30	12.45	38.12	25.79	19.82	0.51	—	—	—	4 739.39	606.05	
1973/74	—	406.77	420.26	213.47	610.20	9.08	36.22	30.21	23.22	0.60	—	—	1 750.03	231.20	
1974/75	—	152.99	459.07	493.12	119.03	340.26	4.79	11.16	16.98	13.05	0.34	—	1 610.79	307.90	
1975/76	54.28	864.30	802.95	357.56	110.29	94.43	177.65	1.52	3.54	5.39	6.63	2.04	2 480.58	339.03	
1976/77	15.70	2 342.82	160.96	228.22	117.51	48.53	38.06	28.02	1.04	5.19	0.09	0.90	2 996.26	348.82	
1977/78	9.32	921.59	525.03	50.98	40.52	14.61	1.65	7.35	13.70	1.35	—	0.57	1 586.67	195.91	
1978/79	15.11	307.44	141.88	49.92	6.77	8.32	3.74	0.56	1.69	1.04	—	—	536.47	80.98	
1979/80	FISHERY CLOSED														

- Note**
1. The lack of fish in the youngest and the older age groups in a number of years might be due to inadequate sampling in those years rather than to their absence from the stock.
  2. Catch tonnage in most seasons includes a small component of herring belonging to the North Sea stock. Wherever possible, this component has been excluded from the catch in numbers at age given above.

## 2. Life history of the Thames Estuary spring-spawning herring stock

### 2.1 Status and identity of the stock

The Thames Estuary herring, sometimes called the Black-water herring, are members of a spring-spawning coastal race which inhabits a number of localities in European waters, the individual stocks being usually rather small. A nearby stock of similar herring, for example, exists in the Wash area of the east coast of England and spawns off Saltfleet just south of the River Humber. Herring of the same type also inhabited the Zuiderzee in Holland until it was closed off from the sea in 1932 (Beaufort, 1954). Other groups of similar coastal spring-spawning herring occur around the coasts of Denmark, particularly in the Danish fjords, and in various parts of the Baltic. Some of the Baltic stocks are relatively large and support annual catches of many thousands of tonnes.

Herring belong to the family Clupeidae which includes closely-related species such as the pilchard and sprat. There are two forms of herring, now considered by many biologists to be only sub species of the same species, the Atlantic herring *Clupea harengus* L. and the Pacific herring *Clupea pallasii* Valenciennes. Characteristically the Pacific herring has fewer vertebrae (VS) and a smaller length at age than the Atlantic herring, also its spawning grounds tend to be situated in more shallow coastal waters. The European coastal herring, of which the Thames Estuary herring form one stock, is therefore much more akin to the Pacific herring than to the Atlantic herring. Tagging experiments during the past 15 years have indicated that the Thames Estuary herring stock is a self-contained unit which does not intermix with other similar stocks in nearby areas to any significant extent.

### 2.2 Egg size and fecundity

In common with other winter-spring-spawning herring, the fecundity of the Thames Estuary herring is relatively low and egg size is relatively large (Blaxter and Hempel, 1963). The eggs at spawning are of diameter approximately 1.5 mm and the larvae at hatching have a comparatively large yolk sac volume of about 0.65 mm<sup>3</sup> (Burd and Wallace, 1971). Fecundity estimates are summarized below by age.

Age (rings at 1 January)	3	4	5	6	7	8	9	10
Mean fecundity (000's eggs)	28	32	35	38	41	44	48	51

### 2.3 Spawning and spawning sites

The Thames Estuary herring spawn in spring from about late February to early May, the onset of spawning probably being governed by the temperature of the water at the spawning sites. In very cold winters it has been observed that spawning may not commence until early April when a water temperature of about 5°C has been reached. This may be a critical temperature for the stock, below which spawning cannot occur.

In any year-class of Thames Estuary herring approximately 99% of the fish mature and spawn for the first time at the age of 3 rings, i.e. when about 36 months old. The remainder are the few individuals which spawn either early at the age of 2 rings or late at the age of 4 rings.

Although part of the stock spawns off the coast of Kent in the Herne Bay area (Figure 2) all available evidence indicates that the major spawning site to date has been the Eagle Bank at the entrance to the River Blackwater in Essex (Figures 1 and 3a, b). In one or two recent years there have been unconfirmed reports of some spawning within the River Blackwater itself in St Lawrence Bay on a shallow part known as 'The Stone' (Figure 4). There are patches of stones and gravel in this locality which suggest that it is perhaps a suitable place for herring to spawn. It is also a fact that both in 1973 and 1974 most of the herring which were caught in a ripe and running state were taken at 'The Stone'. On the other hand, an extensive grab survey conducted in March-April 1979 by the Central Electricity Generating Board Research Division failed to reveal a single herring egg in the St Lawrence Bay area (Dempsey and Bamber, 1980). It is possible, therefore, that herring spawn at 'The Stone' from time to time though not in every year.

Spawning on the Eagle Bank and probably at other spawning sites occurs in waves, with second and third depositions of eggs taking place some days or weeks apart. This has been shown both by an examination of eggs collected on the Eagle Bank and by the length distributions of herring larvae caught in the area in a number of years. The latter usually include two or three distinct size groups consistent with separate hatchings. Larvae hatch some 2-4 weeks after spawning, depending on the temperature of the water, and are initially approximately 8 mm long.

The Eagle Bank is an unusual herring spawning area for European waters because when tides are exceptionally low the crest is uncovered. When this happens during the spawning season the carpet of eggs is exposed to view, as can be seen in the photographs reproduced in Figures 5-7. It is especially interesting to note that the eggs of the Pacific herring are also often uncovered at low tide in some areas, such as British Columbia, apparently without detrimental effect to the eggs through exposure to the air (Outram and Humphreys, 1974). The fact that spawn on the Eagle Bank may occasionally be uncovered, and more frequently be close to the surface of the sea at low water spring tide, could lead to a large-scale destruction of eggs on the shallowest part of the bank if severe weather occurred whilst the eggs were developing. This in fact happened in March 1967 after considerable spawning had taken place. A storm then destroyed all the eggs on the Eagle Bank and afterwards no eggs at all were located during a conical dredge survey of the area. A larval herring survey off the Essex coast in May also recorded virtually all blank hauls. Not surprisingly the 1967 year-class in the Thames Estuary stock turned out to be the worst ever recorded. These were the 3-ring recruit herring during the 1969/70 fishery. It is, of course, interesting to speculate that the herring making up this year-class probably originated only from the Kent coast spawning area.

The 1967 Eagle Bank spawning failure also underlines the very minor importance of the Kent spawning component of the stock at that time. The relative importance of the Kent

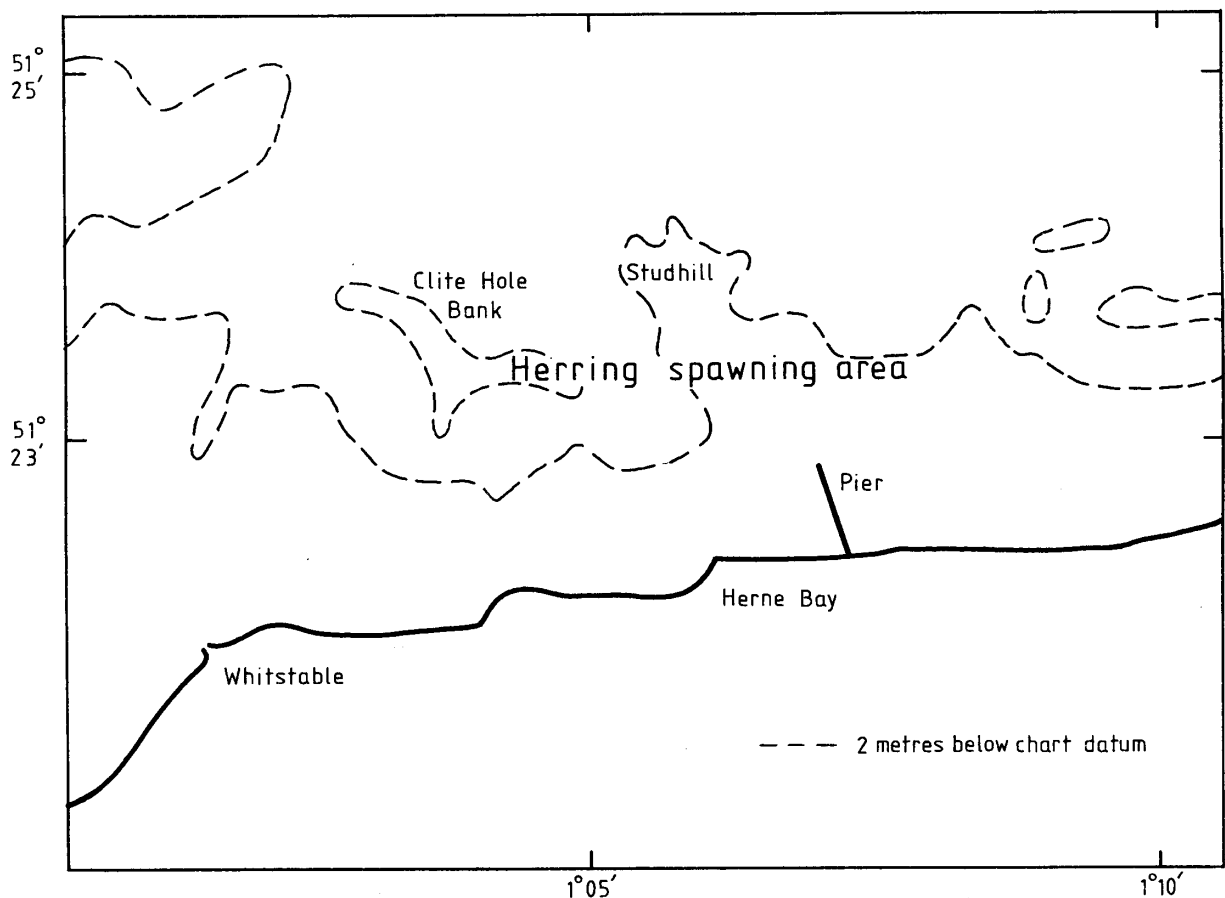


Figure 2 The Herne Bay spawning area. (The centre of this spawning area is believed to be situated between Herne Bay Pier and Studhill.)

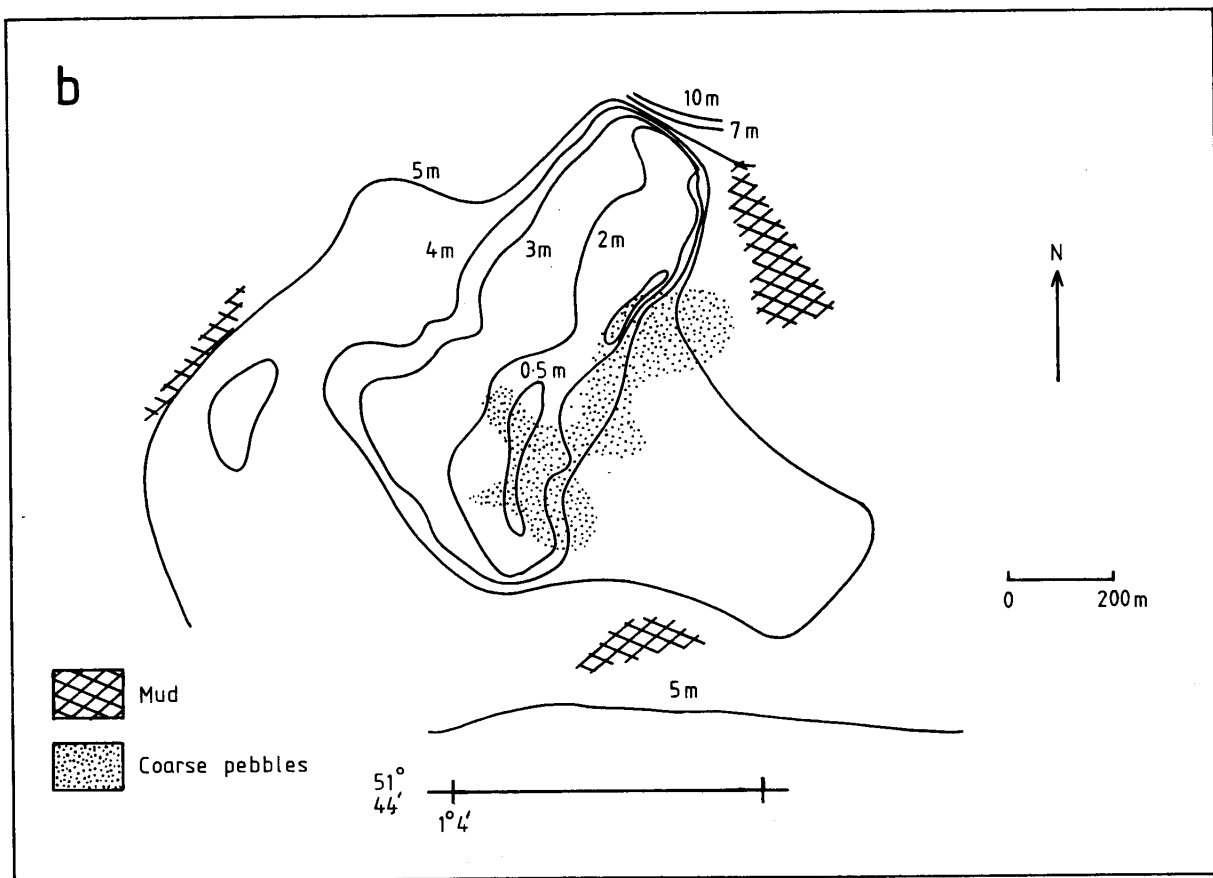
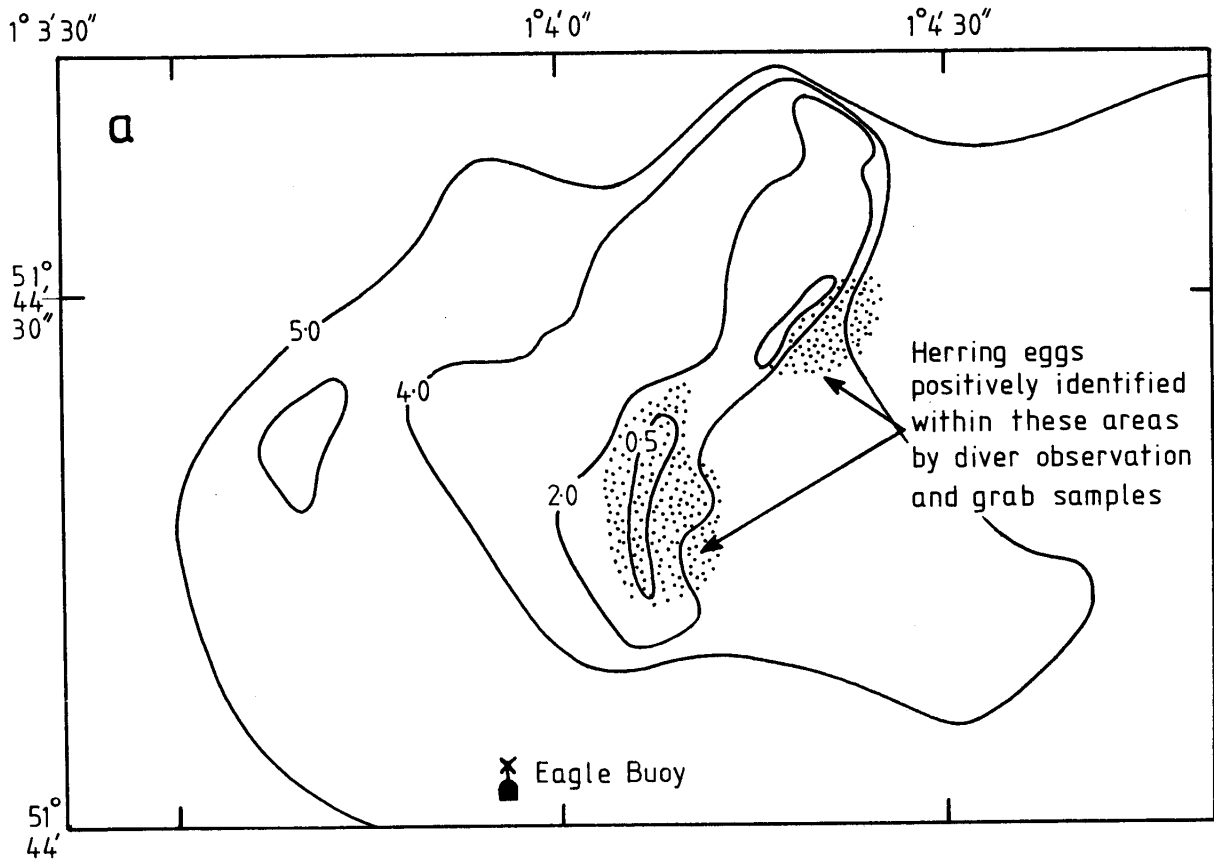


Figure 3 The Eagle Bank.  
 (a) Herring spawning area.  
 (b) Depth contours (metres below Newlyn chart datum) and sediment distribution. Unshaded area is the general heterogeneous sediment. (Reproduced by kind permission of the Director, Central Electricity Generating Board Research Laboratories, from Bamber (1980)).

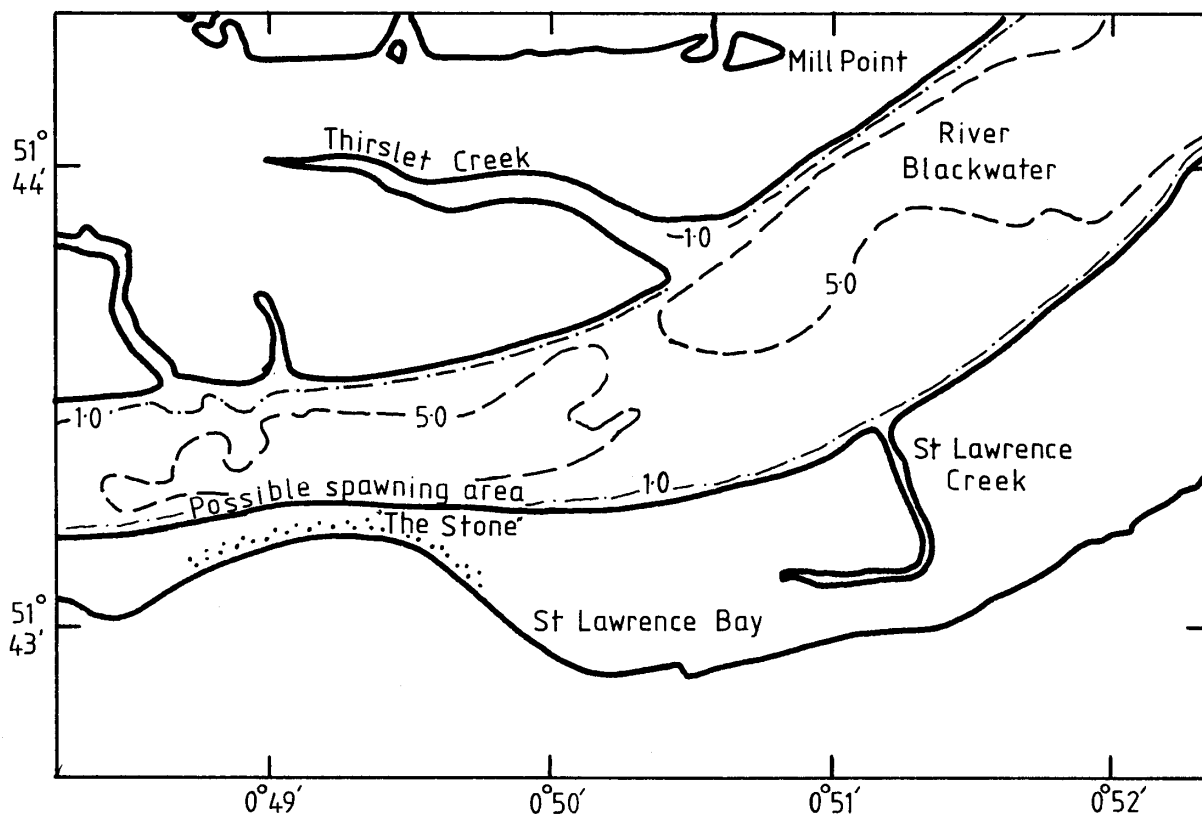


Figure 4 River Blackwater estuary, showing St Lawrence Bay and 'The Stone'. (Contours are metres below chart datum.)

and Essex spawning components to the Thames Estuary stock was more recently investigated by the Ministry of Agriculture, Fisheries and Food (MAFF) by means of a tagging experiment. This was carried out in 1977 from RV NUCELLA during the months of October-December, a period during which both spawning components are known to be well mixed together. An external hydrostatic tag was employed, attached to the fish by means of a thin wire bridle. Altogether 1 112 herring were tagged and liberated, 767 of them in the Thames Estuary and 345 off the Suffolk coast. Of these, 85 were recaptured during the 1977/78 fishery. Although the majority were taken close to their release positions within a few weeks of release, 28 were caught in spawning condition during March 1978. As may be seen in Figure 8, twenty were taken in the Essex area, both on the Eagle Bank and in the River Blackwater, and eight in Herne Bay. When related to the size of the catches of herring in the commercial fishery in these localities, the recaptures indicated that approximately 71% of the stock would have spawned off the Essex coast and 29% off the Kent coast.

Herring eggs have a slightly negative buoyancy. They sink to the sea bed at spawning and quickly adhere to any suitable substrate. Spawning sites normally have a substrate of small stones, gravel or flints overlying gravel (Postuma, Saville and Wood, 1977). The suitability of the Eagle Bank as a major spawning site lies in the fact that the top of the bank is covered by a layer of gravel (Figure 3b). In the

Herne Bay area herring eggs have been brought up by bottom trawl attached to stones and to the 'red weed' *Sphaerococcus*. Other supposedly suitable sites for herring spawning exist within the Thames Estuary but to date none has been shown to be used for this purpose. The possibility that other, at present unidentified, spawning sites are used by the Thames stock cannot, however, be completely ruled out.

#### 2.4 Larvae

Development of the herring larvae within the egg to hatching takes approximately 4 weeks at 5°C and 3 weeks at 7°C. In the Thames Estuary hatching occurs from late March to the middle of May, the length range of the larvae at hatching being 5-10 mm with modal length about 8 mm. The larval herring appear to remain close to the coast during the following months; some find their way into adjacent rivers and inlets whilst others are carried further afield by the currents. Growth is fairly rapid during the summer months and by July-August, when a length of 30-35 mm has been reached, the fish pass through the metamorphosis, becoming completely scaled and acquiring the adult form.

#### 2.5 Juveniles

*O-group*: The actual dispersion of the larvae can best be deduced by an examination of the distribution of the O-group herring, i.e., fish beyond the larval stage and metamorphosis, in their first year of life. The identification of



Figure 4. Herring spawn on the crest of the Eagle Bank uncovered at low tide 10 April 1963.



Figure 5. Herring spawn on the crest of the Eagle Bank uncovered at low tide 10 April 1963.

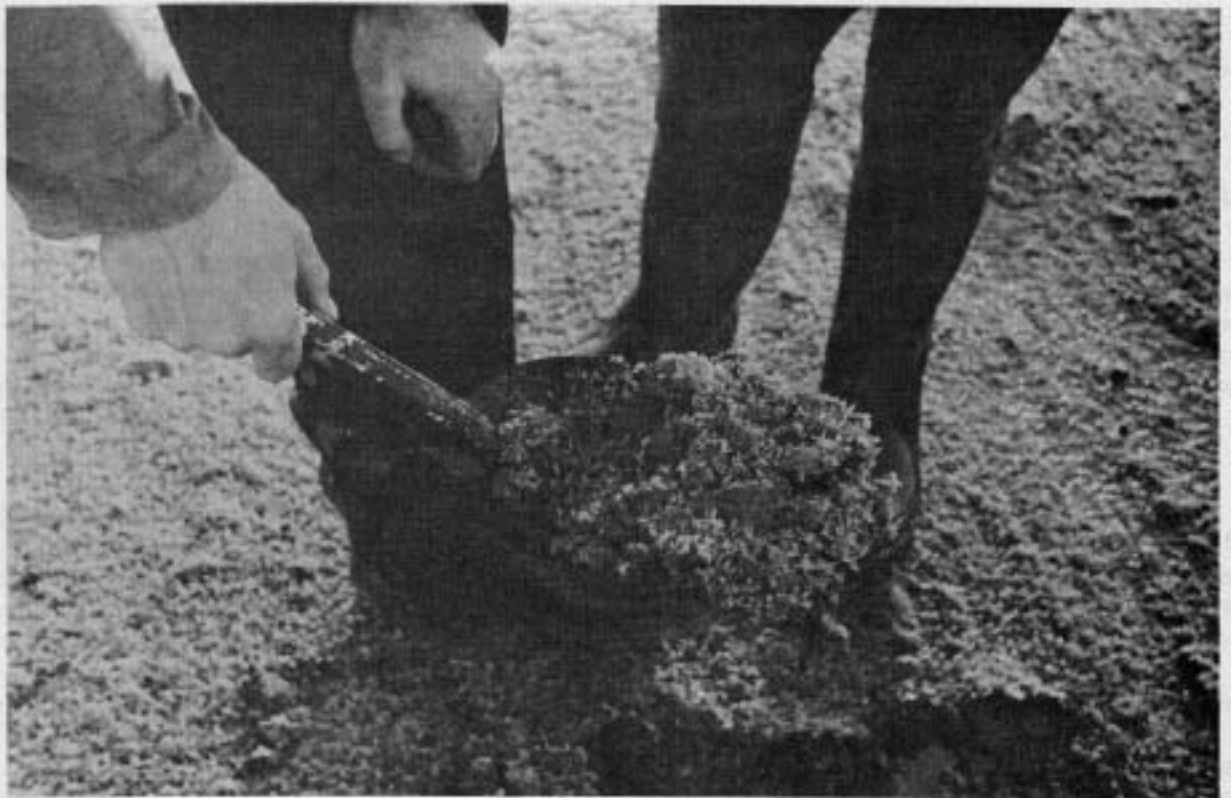


Figure 6 Exposed Eagle Bank herring eggs and gravel being removed for examination.

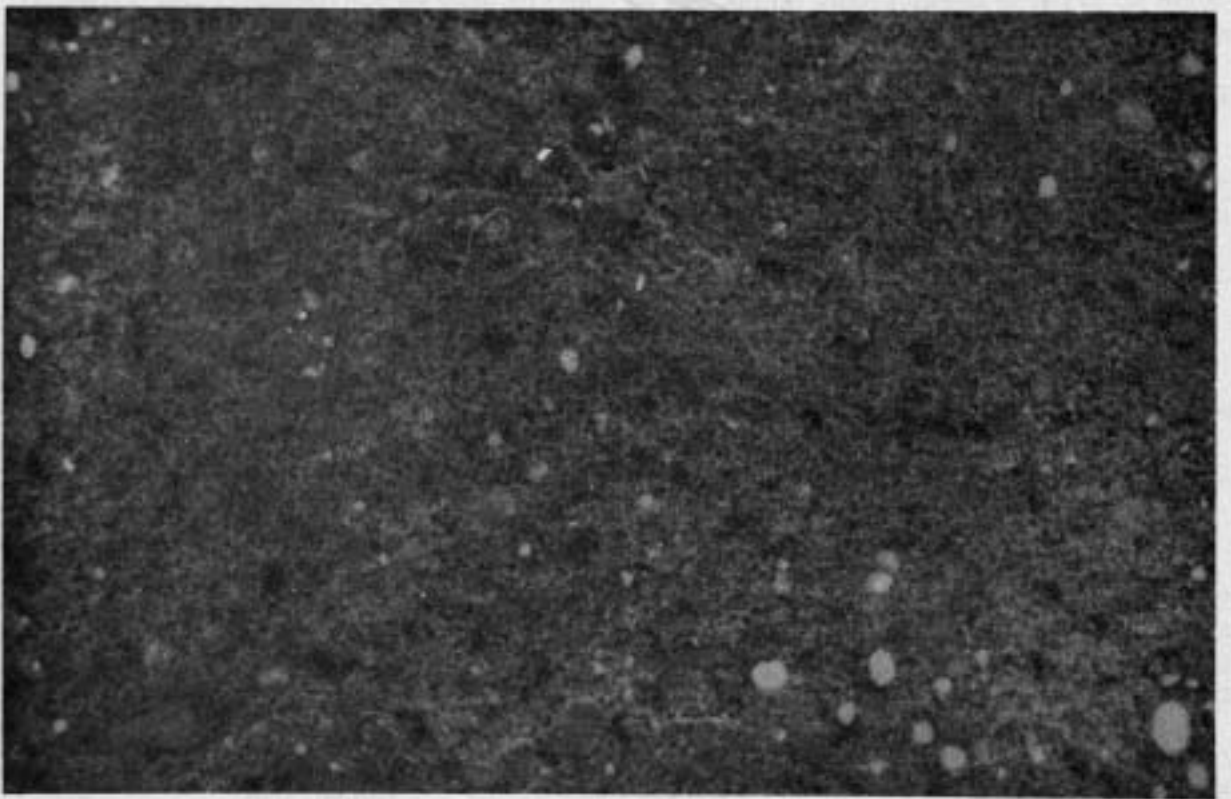


Figure 7 Thin deposition of herring eggs on Eagle Bank at edge of patch still covered by a few inches of water.

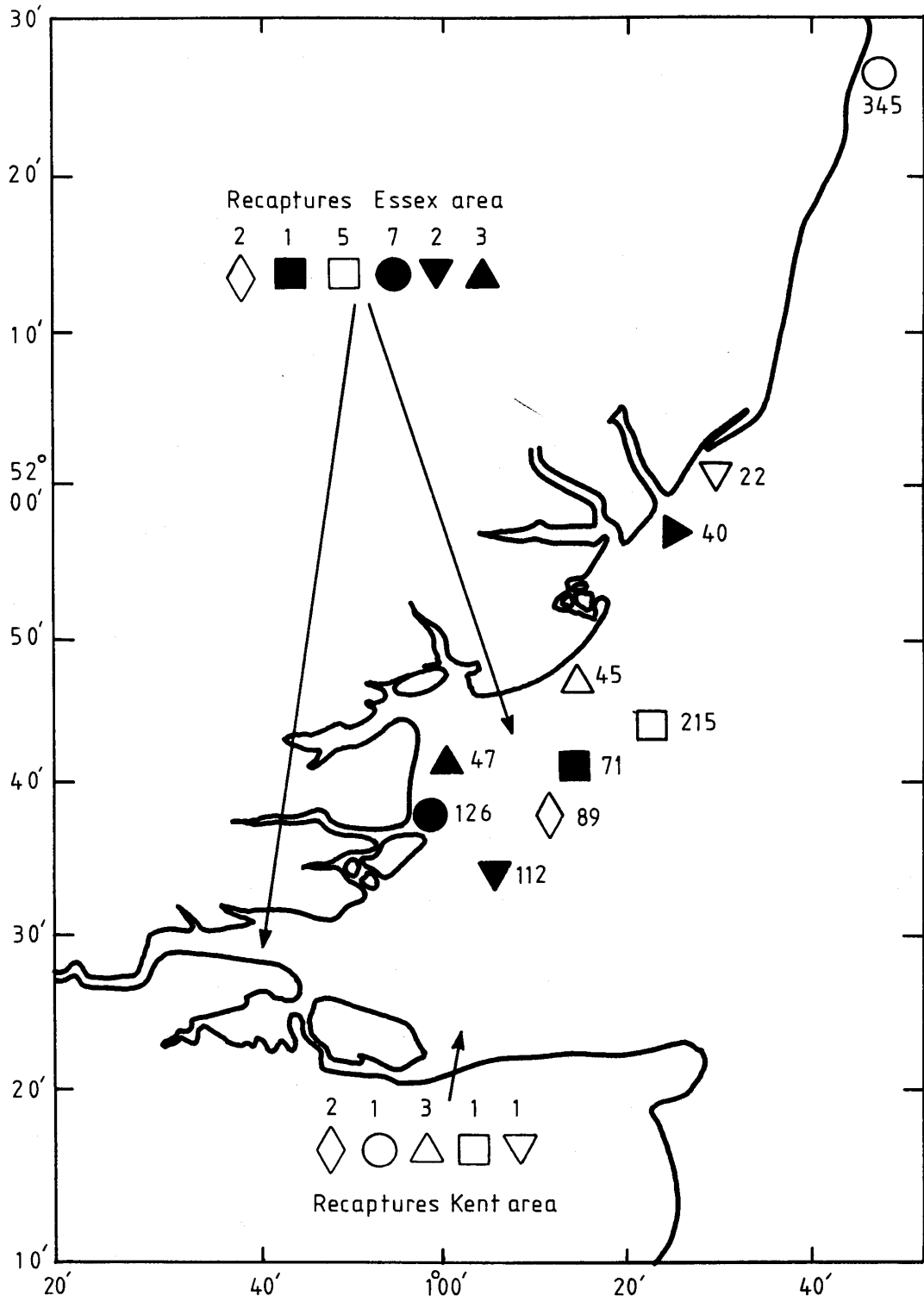


Figure 8 Numbers and release positions of herring tagged in October-December 1977 and recaptures in the Kent and Essex spawning areas in March 1978 (numbers beside symbols).

O-group herring of the Thames Estuary stock is a simple matter. Not only can they be distinguished from members of the North Sea stock by their characteristic shape and small size, typical of spring-spawned herring, but also they have fewer vertebrae and fewer keel scales (between the pelvic fins and anus ( $K_2$ )). Thames herring have a mean vertebral number (VS) approximately 54.0 – 55.5 and a mean  $K_2$  approximately 13.3–14.5. O-group herring of the Downs component of the North Sea stock, with which they are most likely to be mixed, have higher values of mean VS and mean  $K_2$ , these being approximately 56.3–56.9 and 13.8–14.8 respectively. Although most are retained within the Thames Estuary the widespread dispersion of some of the Thames Estuary herring larvae is evident from the fact that samples of the typically low VS O-group herring have occasionally been taken in such localities as Lowestoft and Sizewell along the East Anglian coast to the north and Deal on the Kent coast to the south. Samples have, of course, also been obtained at many places within the Thames Estuary proper. Details of a number of samples, selected on a geographical basis, are given in Table 2. It is of interest to note that O-group herring have become much more abundant in the lower reaches of the River Thames since the programme to clean up the river has become effective during recent years. These fish are now regularly taken in substantial numbers on the cooling water intake screens at the CEGB power station at West Thurrock and also in the Southend whitebait fishery. In winter, O-group herring tend to move offshore into deeper water and become more scattered (Wood, 1959). By the time that Thames Estuary herring are first classified as 1-group rather than O-group (i.e. after 12 months) they are about 5-12 cm long.

*1-group*: During winter when the herring become 1 year old a ring is formed at the edge of their otoliths and scales. For convenience in age determination, 1 January is designated as their birthday and for the rest of the year the fish are considered to be 1-group or 1-ring herring or 1-year-olds. Few of the Thames Estuary spring-spawning herring are in fact caught during their second year of life. To some extent this is because they are not of a marketable size, but a few are seen in sprat and whitebait catches, and others are sometimes taken during research cruises. Small samples which have been obtained in recent years are listed in Table 3. By the time that the Thames Estuary herring become 2 years old, i.e. after 24 months, they have grown to a length of some 15-22 cm.

## 2.6 Recruits and adults

The Thames Estuary herring nearly all mature for the first time, and recruit to the fishery, during their third year of life as 2-ring fish. During autumn they migrate back into the Thames Estuary from adjacent areas. A southerly movement along the East Anglian coast was clearly shown by the 1977 tagging experiment (of both recruit and adult herring). Along the Kent coast a fishery normally takes place off North Foreland in October and November on Thames Estuary herring which, at that time, are also probably migrating back into the estuary from the south. The Thames Estuary herring spawn for the first time when about 36 months old, i.e., as 3-ring fish. The mean length and mean weight at age of recruit and older herring taken in the commercial fishery are given in Table 4; some values for East Anglian winter-spawning herring of the North Sea stock at comparable ages are also included. This clearly

**Table 2** Details of samples of low VS spring-spawned O-group herring from various localities. Numbers of fish examined are given in parentheses.

Date	Location	Length range (cm)	Mean VS	Mean $K_2$
4 Aug 1953	Lowestoft	2.5– 6.9	55.21 (120)	–
16 Sep 1955	”	5.0– 7.4	54.77 ( 50)	–
5 Oct 1966	”	5.0– 6.9	55.49 ( 35)	–
15 Oct 1968	”	5.9–10.0	55.18 ( 40)	14.30 (40)
12 Jun 1972	Sizewell	4.5 – 5.9	55.95 ( 21)	–
21 Dec 1972	”	6.5– 8.4	55.33 ( 21)	14.00 (21)
2 Aug 1955	Orfordness	3.5– 5.7	55.00 ( 24)	–
3 Aug 1955	Brightlingsea	2.5– 4.9	54.93 ( 30)	–
10 Jan 1966	River Blackwater	7.3–10.8	55.33 ( 60)	–
12 Nov 1967	”	6.5– 9.9	55.77 ( 26)	14.46 (26)
5 Mar 1969	”	6.9–10.5	55.25 ( 57)	14.46 (57)
11 Jan 1970	Swire Hole (Wallet)	6.2– 9.8	55.10 ( 21)	14.14 (21)
30 Oct 1979	River Crouch	4.9– 6.8	54.82 ( 50)	13.76 (25)
10 Aug 1978	Southend	4.9– 8.7	54.85 ( 33)	–
26 Oct 1979	”	4.5– 8.6	54.88 ( 57)	13.84 (37)
3 Oct 1978	West Thurrock	5.7–10.9	55.21 ( 48)	13.56 (45)
10 Sep 1979	”	5.2– 8.6	55.00 ( 42)	13.73 (44)
4 Jul 1979	Herne Bay	5.4– 6.5	55.56 ( 16)	–
18 Sep 1979	”	5.1– 7.6	54.88 ( 24)	13.92 (24)
4 Aug 1955	Deal	2.5– 4.4	54.61 ( 45)	–

**Table 3 Samples of 1-group low VS spring-spawned herring**

Date	Location	Length range (cm)	Mean VS	Mean K <sub>2</sub>
24 Jul 1979	Lowestoft	12.8–15.5	55.19 (31)	13.74 (23)
11 Jan 1970*	Swire Hole	15.3–17.3	55.06 (18)	14.39 (18)
1 Jul 1969	Southend	10.7–13.7	55.00 (16)	13.88 (16)
14 Nov 1978	"	16.7–22.0	54.94 (101)	–
14 Jan 1971*	Queens Channel	16.1–19.5	55.00 (22)	13.91 (23)
20 Jul 1979	Margate Roads	12.8–14.7	55.05 (21)	13.95 (21)

\*Technically these samples were composed of 2-group fish, as they were taken after 1 January, yet the herring were only approximately 22 months old.

**Table 4 Mean weight at age and length at age of Thames Estuary herring, 1962-74 and 1974-79, and of North Sea herring**

Age in rings at 1 January	Thames Estuary		Southern North Sea
	1962/63 to 1973/74	1974/75 to 1978/79	
<i>Mean weight at age (g)</i>			
3	93	103	146
4	123	137	186
5	140	157	214
6	149	170	234
7	156	180	252
8	161	187	267
9	164	191	283
10	167	194	298
11	169	195	312
<i>Mean length at age (cm)</i>			
3	22.70	23.25	24.01
4	24.42	25.03	25.47
5	25.49	26.22	26.91
6	26.15	27.11	28.32
7	26.53	27.58	28.69
8	26.89	28.10	29.80
9	27.08	28.35	30.29
10	27.23	28.61	–
11	27.25	28.63	–

illustrates the point made earlier that these coastal spring-spawning herring are relatively quite small compared with the more usual Atlantic herring. This fact has an important influence on the market price which is paid for Thames herring, particularly if the catch includes a high proportion of small recruits. Mean length and mean weight at age are given for Thames Estuary herring during two periods, from 1962/63 to 1973/74 and from 1974/75 to 1978/79. It can be seen that in the latter period the herring have tended to be somewhat longer and heavier than in the earlier period. The reason for this is not clear, but over the past 30 years increases in length and weight have been noted in other herring stocks, some of which seem to have been associated with a more plentiful supply of food. The size of the

Thames Estuary stock was certainly considerably larger in a number of the years during the earlier period from 1962/63 to 1973/74, so that many more fish would then have been competing for the available food, and this might have had some influence on growth. Since 1973/74, the maximum length reached by Thames Estuary herring has been about 29 cm, whilst the oldest fish of this stock so far recorded was aged 15 rings. This age is, however, quite exceptional and very few fish survive beyond an age of 11 or 12 rings.

### 2.7 Distribution of the adult stock during winter

The distribution of the adults within the Thames Estuary during the winter months is illustrated in Figure 9. Catches are taken off North Foreland during October and November when concentrations of herring are also fished in the Middle Deep, Southwest Reach, East Swin (or Kings' Channel) and the Wallet. At that time only small numbers of herring appear to be distributed outside these areas. Later, as spawning time approaches, concentrations form in the spawning areas and in the early months of the year catches are mainly taken in Herne Bay, the Eagle Bank area and in the River Blackwater.

### 3. Methods employed in herring stock assessment

A number of standard techniques have been used in the course of making the assessments on the Thames Estuary herring stock which are referred to in later sections of this report. It is appropriate, therefore, to discuss them briefly here.

#### 3.1 Yield per recruit

In fish stock assessment, when growth parameters and rates of mortality are available for a particular population, it is possible to incorporate these into a mathematical model in order to describe the changes in the population size which occur if the value of one or more of the stock parameters is altered. When recruitment is not accurately known it is usual to work in terms of yield per recruit (YPR) taking into account the growth characteristics of the fish and the exploitation pattern of the stock. For the Thames Estuary herring stock the calculation of expected yield in weight has been made from the exploited age groups, at specified levels of

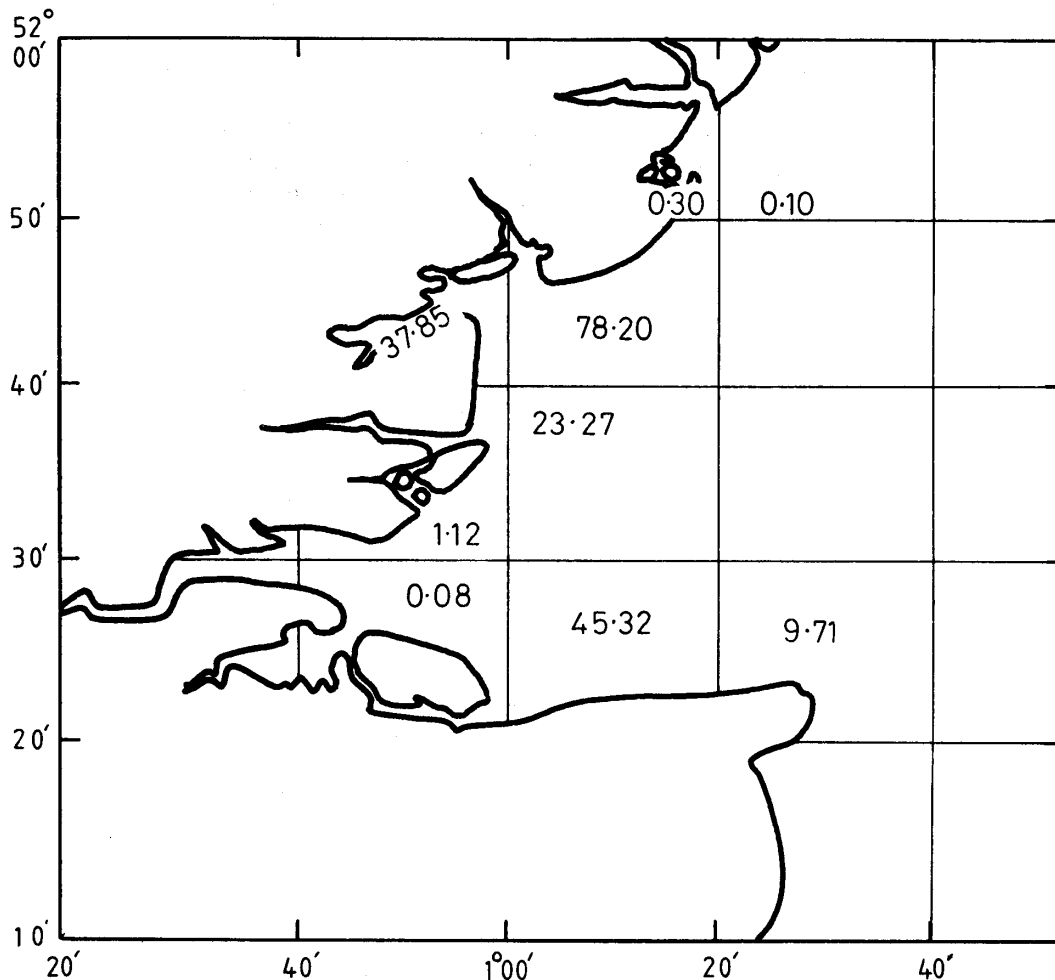


Figure 9 Distribution of the commercial herring catch, in tonnes per statistical rectangle, for the fishery September 1977-March 1978 (total 196 t).

fishing mortality, using the sums of products method incorporated into the model of Shepherd (1980). Thus

$$YPR = \sum_{i=0}^{N-1} P_i W_i \frac{F_i}{Z_i} (1 - e^{-Z_i}) + P_n W_n \frac{F_n}{Z_n}$$

where  $P_0 = 1$ ,

$$P_i = (e^{-Z_i}) P_{i-1}$$

$W_i$  = mean weight at age  $i$  in grams in the catch,

$$F_i = \hat{F} S_i$$

$\hat{F}$  = fishing mortality at the same reference age,

$S_i$  = fractional exploitation at age  $i$  (referred to unity at same reference age),

$Z_i = F_i + M$  ( $Z_i$  being the instantaneous coefficient of total mortality at age  $i$ ,  $F_i$  the instantaneous coefficient of fishing mortality at age  $i$  and  $M$  the instantaneous coefficient of natural mortality)

and the  $n$ th age group includes all fish of age  $n$  years and older.

As already discussed, Thames Estuary herring mature and recruit to the adult stock during autumn and spawn at the age of 3 rings the following spring. Curves of both yield per recruit and biomass per recruit have been constructed for Thames Estuary herring during the two different growth periods 1962-1974 and 1974-1979. The exploitation pattern (which is discussed in a later section) also differed during these two periods. Three- and 4-ring fish were not fully exploited up to 1973/74 but have been since then. This accounts for the difference in shape of the two yield per recruit curves which are plotted in Figure 10. The biomass per recruit curves plotted in Figure 11 are, however, rather similar for both periods. A natural mortality coefficient of  $M = 0.1$  (10%) has been applied to all ages of Thames Estuary herring, a similar value to that normally assumed for the North Sea herring stock. As with other herring populations, the yield per recruit curves are relatively flat topped. Above a fairly low level of fishing mortality of  $F = 0.3$ , further increases in  $F$  produce only small gains in yield per recruit up to  $F_{max}$ , and beyond this point actually result in a decrease. Biomass per recruit declines rapidly between  $F = 0.1$  and  $F_{max}$ , so that fishing at  $F_{max}$  would seriously deplete the stock and might eventually result in recruitment failure. A safe optimum sustainable yield point for the Thames Estuary stock would

be about  $F = 0.3$ , although a more appropriate long-term management objective would be to fish at the  $F_{0.1}$  point on the yield curve (the point where the slope of the curve is  $1/10$  of the slope at the origin which, for the Thames Estuary herring stock, is at a value of about  $F = 0.2$ ). This would allow a 'buffer stock' to be maintained in order to offset any short-term reductions in recruitment.

### 3.2 Estimation of current level of fishing mortality

Total instantaneous mortality rates ( $Z$ ) can be calculated from catch per unit effort data in the manner described by Gulland (1969). If  $N_0$  and  $N_t$  are the abundances of any group of fish at two known times then the total mortality coefficient ( $Z$ ) is given by

$$Z_t = \log_e \frac{N_0}{N_t}$$

where  $t$  = the interval in time.

In the special case where abundances are obtained annually and  $t = 1$  year,

$$Z_t = \log_e \frac{N_0}{N_1}$$

and  $F_t = Z_t - M_t$ ,

where  $N_0$  = initial abundance in number of fish

and  $N_1$  = abundance in number of fish 1 year later.

Catch per unit effort data can be used in this way to estimate current  $F$ , provided that the exploitation pattern is unchanged. Effort should be similar in the years under consideration. It might also be possible to use catch per unit effort data in a changing fishery, provided that the changes in effective fishing effort were accurately known. In practice this is extremely difficult or even impossible to measure in a herring fishery, particularly one taking place when the fish are either close to or actually in the act of spawning. Because herring spawning beds are extremely limited in size, high concentrations of herring can occur for short periods at this time even when the stocks have been reduced to a small size. Moreover, intensive fishing can still take place, for example with purse-seine nets, because the whole of the adult stock is then confined in a small area.

### 3.3 Estimation of stock size from current fishing mortality

Provided that a value of current  $F$  of acceptable accuracy can be obtained from catch per unit effort data, then stock sizes both at the beginning of the current year ( $t$ ) and at the end ( $t + 1$ ) can be obtained from the number of fish caught during that year from

$$N_t = \frac{C_t}{\frac{F}{Z}(1 - e^{-Z_t})}$$

and  $N_{t+1} = N_t \times e^{-Z_t}$ .

### 3.4 The virtual population analysis

The annual catches of a year-class during its exploited life can be used to estimate annual mortalities and abundances using methods which have been called virtual population analysis (VPA) (Fry, 1957; Bishop, 1959; Jones, 1964; Gulland, 1965). A value for  $F$  in the last year of exploitation has to be assumed if one of acceptable reliability is not available. Then, using

$$C_t = \frac{F}{Z} N_t (1 - e^{-Z_t}),$$

the population number ( $N$ ) in the year ( $t$ ) can be calculated. Working backwards in time through the sequence of catches, the population size to give each catch can be calculated from the above equation and

$$N_t = \frac{N_{t+1}}{e^{-Z_t}},$$

while the value of fishing mortality ( $F$ ) in a given year ( $t$ ) is estimated from the catch in that year and the number of survivors at the end of that year, so that

$$\frac{N_{t+1}}{C_t} = \frac{e^{-Z_t}}{\frac{F}{Z}(1 - e^{-Z_t})}.$$

The second part of the above equation is only dependent on  $F_t$ . The equation is solved in a computer program by an iterative procedure.

Both VPA and an approximation to it described by Pope (1971) and called cohort analysis have been widely used in fish stock assessment in recent years. They each provide a valuable estimate both of population size and of fishing mortality (provided that a realistic value of  $M$  is available) for all but the most recent 2-3 years, from catch in number at age data. The most serious discrepancy with an analysis of this type, however, is that in most cases a judgement has to be made on the rate of fishing mortality in the last year for which catch at age data are available. The abundance at age in that last year together with both the abundance at age and estimates of fishing mortality one year earlier are very largely determined by this estimate of fishing mortality (the input  $F$ ). The problems of obtaining a reliable input  $F$  for a herring fishery have already been discussed, but an additional complication so far as the Thames Estuary stock has been concerned in recent years arose because fishing was controlled by a quota system, which varied from year to year. However, in spite of the above reservations, both the VPA and the cohort analysis do provide valuable information on past events, and in the absence of any other independent measure of stock size they remain the most useful methods of assessment available.

### 4. Management of the Thames Estuary herring fishery since 1975

Following a period in the early 1970s when herring fishing within the Thames Estuary was restricted by conservation

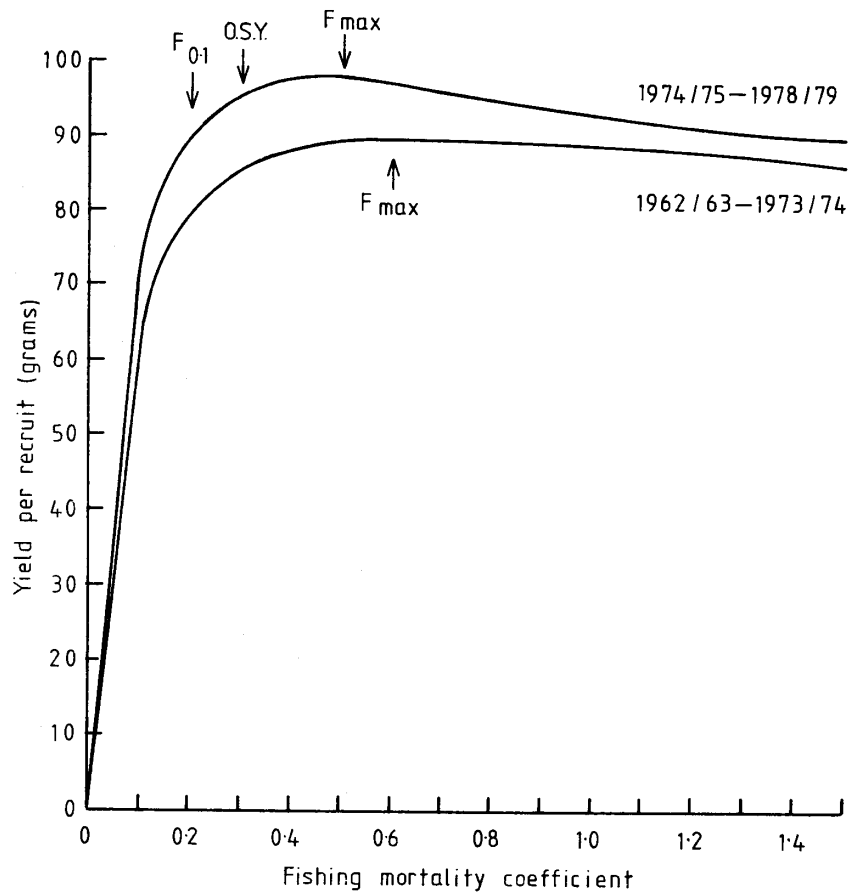


Figure 10 Yield per recruit curves for Thames Estuary herring.

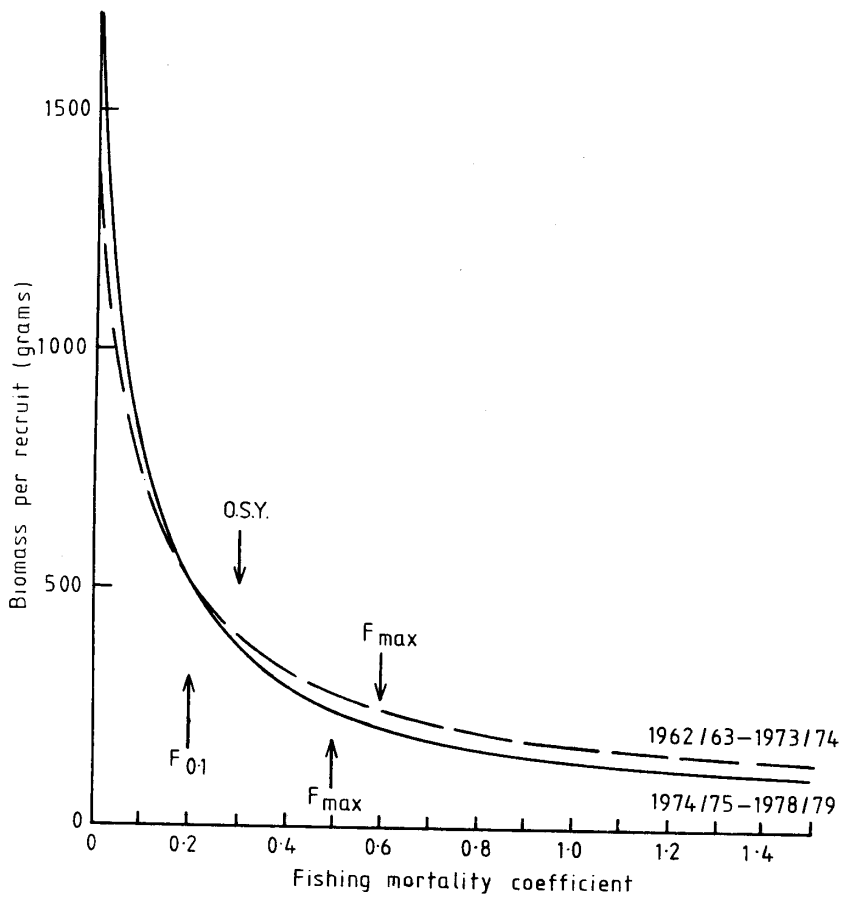


Figure 11 Biomass per recruit curves for Thames Estuary herring.

measures aimed at improving the North Sea herring stock, the North East Atlantic Fisheries Commission in November 1975 decided to exclude the Thames Estuary from any further regulations because it had been shown that the Thames Estuary fishery exploited a quite separate stock of local herring.

A meeting of all interested parties was held at West Mersea on 2 January 1976 when it was decided to form a Thames Estuary Herring Management Committee, aimed at conserving the herring stocks in the area and rationalizing marketing arrangements. The Management Committee was made up of a number of port representatives plus a member to represent the herring drifters. The ports to be represented were Harwich, West Mersea, Brightlingsea, Burnham-on-Crouch, Southend and Whitstable. Subsequent meetings of the Management Committee were also attended by members of official organizations such as the relevant Sea Fishery Committees, the White Fish Authority and the Ministry of Agriculture, Fisheries and Food (MAFF).

*1975/76* A preliminary cohort analysis carried out on the Thames Estuary herring stock by MAFF some years prior to the setting up of the Management Committee and covering the years up to 1973 had indicated a maximum spawning stock size in excess of 1 000 t (Table 5) and from the recruitment levels which had been indicated it was considered that an annual catch of some 400 t would be possible. This information was passed to the Management Committee at its first meeting, by which time a substantial catch had already been taken in the 1975/76 fishery. It was advised that the total catch for the season should be kept below 400 t as recruitment appeared to be rather poor. The Management Committee therefore introduced a quota

system to limit catches and this was maintained until fishing ceased in April 1976. This factor, together with the unusually dispersed distribution of the fishery, led to the total recorded catch being restricted to 330 t (see Table 1). Because of the imposition of quotas, the usual method of estimating fishing mortality by comparing the catch per unit effort in successive years became invalid. From the recorded catch it was estimated that the fishing mortality during 1975/76 might have been between  $F = 0.4$  and  $F = 0.6$  (33 and 46%) on the basis of fishing mortality estimates derived from the preliminary cohort analysis. Provided that this range of fishing mortality was approximately correct, it meant that the adult stock at the start of the 1975/76 fishery would have been between about 600 and 800 t, leaving a stock at time of spawning of some 250-450 t. This was well below the high stock levels estimated in earlier years and gave cause for concern, particularly as recruitment of the 1973 year-class had been poor.

*1976/77* The assumed range of fishing mortality in 1975/76 gave an estimated surviving adult stock at the start of the 1976/77 fishery of only 350-550 t. A total allowable catch (TAC) of 200 t was therefore recommended provisionally, until the strength of the incoming 1974 recruit year-class could be assessed. It soon became clear in the early winter months that the 1974 year-class was in fact a good one, so the TAC was revised to 300 t. The fishery in 1976/77 was conducted under licence (issued by MAFF) and catches were again restricted by the Management Committee under a quota system to 1.27 t (200 stones) per boat per day, for a 5-day week.

When the TAC was revised to 300 t it was noted that in the previous decade the good year-classes had been common to

**Table 5 Thames Estuary herring: adult stock size in thousands of fish per age group, from VPA**

Age in rings at 1 January	Years	1962/ 63	1963/ 64	1964/ 65	1965/ 66	1966/ 67	1967/ 68	1968/ 69	1969/ 70	1970/ 71	1971/ 72	1972/ 73	1973/ 74	1974/ 75	1975/ 76	1976/ 77	1977/ 78*
3		1 332	1 989	1 631	4 826	5 176	2 361	4 29	123	6 728	2 563	2 536	1 612	1 459	1 169	3 176	1 322
4		388	649	1 369	1 233	3 505	3 082	1 572	304	54 5 071	2 051	1 219	1 074	1 175	245	672	
5		532	216	307	1 088	619	1 266	1 737	916	159	43	3 669	552	705	537	307	70
6		143	147	117	227	812	196	662	946	207	134	36	1 320	298	174	149	64
7		250	87	48	64	103	233	102	424	182	139	109	20	617	157	53	25
8		144	57	29	30	25	47	108	69	43	108	93	62	10	237	53	3
9			22	6	12	17	8	21	73	4	25	76	60	22	4	48	12
10								3	11	3	2	6	50	26	10	3	17
11									1				5	23	7	5	1
12														4	9	2	-
13															3	1	1
Total		2 789	3 177	3 507	7 480	10 257	7 193	4 634	2 867	7 380	8 083	8 576	4 900	4 238	3 482	4 042	2 188
Spawning stock biomass (t)		330	345	394	803	1 143	850	612	409	722	932	1 053	606	586	474	459	261

Input  $F = 0.6$  on all ages in 1978/79 (the last year for which catch in number data are available).

\* Inefficient estimates.

both the Thames Estuary and North Sea herring stocks simultaneously. This was true of the 1974 year-class, but at that time the 1975 and 1976 year-classes in the North Sea stock had already been assessed as very weak ones. It was therefore pointed out that the 1974 year-class, then recruiting to the Thames Estuary stock, might have to sustain both the spawning stock and the fishery to a considerable extent for a total of three seasons. Because of this it was stressed that the total catch taken in 1976/77 should not be allowed to exceed 300 t. Unfortunately the quota system failed once herring concentrated for spawning in the Herne Bay area in early March and some very substantial catches had been taken within the next few days. By the time that licences were withdrawn in mid-March and all fishing ceased the recorded catch had reached almost 350 t. As the Thames Estuary herring are also fished by so-called 'hobby fishermen', particularly at weekends, the total actual catch taken during 1976/77 was probably well in excess of this figure. The failure to adhere to the 300 t TAC had serious consequences. Nevertheless, at the time, there were bitter complaints from most of the fishermen that the fishery had been closed when 'the sea was alive with herring' and that fishing should have been allowed to continue for several weeks longer.

*1977/78* After the end of the previous fishery a new cohort analysis was carried out using all the catch in number at age data which had been assembled since 1962/63. It was clear from this analysis that the size of the spawning stock had declined to only about half of its earlier high levels and that the assumed range of fishing mortality in 1975/76 had been too optimistic. Furthermore the revised estimate gave the spawning stock biomass at the start of the 1975/76 fishery as only about 500 t, so the stock had obviously been overexploited in both the 1975/76 and 1976/77 fisheries. It was impossible to obtain any reliable estimate of fishing mortality in those seasons from either the cohort analysis or from catch per unit effort data (because of variation in the quota limits set) but it was possible to estimate fishing mortality during the months of January and February 1977 using only drifter catch per effort data, as similar quotas were also in operation during those months in 1976. The value obtained was  $F = 0.8$  (55%), a point well above  $F_{\max}$  on the yield-per recruit curve. In the absence of any other estimate it had to be assumed that this value of fishing mortality was appropriate for the whole of the 1976/77 fishery. A calculation of the stock size of surviving adults made on this basis for the start of the 1977/78 fishery gave approximately 400 t of adult stock, so a provisional TAC of 150 t was recommended, to be reviewed once the strength of the 1975 recruit year-class had been assessed. This TAC was based on a value of fishing mortality for 1977/78 of  $F = 0.4$  and represented a reduction of 22% in fishing mortality from the 1976/77 level. All of this was, of course, completely dependent on the estimate of  $F = 0.8$  for the previous fishery being realistic.

The 1975 year-class was fairly well represented in the early catches which were taken, and the drifter catch per effort was reported to be good (i.e., number of fish caught per net). It was concluded that the 1975 year-class was a moderately good one and the TAC was increased to 190 t. This TAC

was taken up by the middle of March 1978 and licences were then withdrawn. The total recorded catch for the season was almost 196 t.

*1978/79* Again there was a major problem after the 1977/78 fishery was over in trying to estimate the level of mortality which the catches during that fishery had generated. A number of cohort analyses were carried out with values of input  $F$  in 1977/78 within what was considered to be the probable range, i.e., from  $F = 0.4$  (33%) to  $F = 1.0$  (63%). The results gave considerable cause for concern. Not only did they indicate that fishing mortality in 1975/76 (the last reliable year) was at a much higher level than had been suspected, i.e., about  $F = 1.2$  (70%), but they also indicated a very significant change in the exploitation pattern on the Thames Estuary stock. From 1962/63 to 1974/75 fishing mortality on the recruit 3-year-old herring was at about only half the level of that on fish of 5 years and older, while that on the 4-year-olds was intermediate (Table 6). In 1975/76, however, fishing mortality had been highest on the recruit 3-year-olds and slightly lower on the older fish. The reason for this change was not clear but a possible cause was the decline in the abundance of the older herring, with the fishery being more directed towards the recruits than had previously been the case. In view of this, the stock of surviving adult herring at the start of the 1978/79 season was calculated for two different levels of 1977/78 fishing mortality. The first calculation was based on  $F = 1.0$  (63%) on all age groups. The second was based on  $F = 0.6$  (46%) on 4 years and older fish, this being the mortality rate generated by the catch which was taken in 1977/78 from the revised stock in number of fish at the beginning of that fishery, and  $F = 0.8$  (55%) on the recruit 3-year-olds, to take account of the change in exploitation pattern. The resultant adult stock sizes for 1978/79 were 112 and 194 t. The first value was so low that, if it had been accepted as realistic, no fishery during 1978/79 could have been advocated. However, in discussions with fishermen at a meeting of the Management Committee in July 1978, the view generally expressed was that herring had not been scarce or difficult to catch during the previous season and that the lower stock size estimate was over-pessimistic. It was therefore decided to accept the higher value of 194 t as the more realistic of the two estimates and on this basis to advise a TAC of 60 t for the 1978/79 fishery, this to be revised, as in earlier seasons, once the level of recruitment by the 1976 year-class had been assessed.

It became clear towards the end of 1978 that, estimated by comparison with the older fish of known abundance in the catches, the recruiting 1976 year-class was a poor one, at less than 0.6 million 3-year-olds, and therefore well below the long-term mean recruitment value of 2.4 million fish for this stock. At a meeting of the Management Committee held on 15 December, at which all information on the level of catch per unit effort and the distribution of the catches during the previous two months was considered, it was decided to set a final TAC for the season at 80 t, this being the maximum permissible catch if a satisfactory level of spawning stock was to be maintained. This, of course, was again based on the assumption that the adult stock was 194 t at the start of the fishery and that the recruits had

**Table 6 Thames Estuary herring: fishing mortalities by age and years, from VPA**

Age in rings at 1 January	Years																
	1962/ 63	1963/ 64	1964/ 65	1965/ 66	1966/ 67	1967/ 68	1968/ 69	1969/ 70	1970/ 71	1971/ 72	1972/ 73	1973/ 74	1974/ 75	1975/ 76	1976/ 77	1977/ 78*	
3	0.62	0.27	0.18	0.22	0.42	0.31	0.24	0.72	0.18	0.12	0.63	0.31	0.12	1.46	1.45	1.29	
4	0.49	0.65	0.13	0.59	0.92	0.47	0.44	0.55	0.12	0.22	1.21	0.45	0.59	1.24	1.15	1.66	
5	1.19	0.52	0.20	0.19	1.05	0.55	0.51	1.39	0.07	0.09	0.92	0.52	1.30	1.18	1.48	1.40	
6	0.40	1.01	0.49	0.70	1.15	0.55	0.35	1.55	0.30	0.11	0.46	0.66	0.54	1.08	1.69	1.09	
7	1.21	0.99	0.36	0.85	0.67	0.67	0.29	2.19	0.42	0.30	0.46	0.62	0.86	0.99	2.73	0.95	
8	1.77	2.38	0.77	0.50	1.05	0.71	0.29	2.88	0.43	0.25	0.34	0.93	0.70	1.50	1.38	0.79	
9						0.96	0.57	3.00	1.96	1.30	0.32	0.75	0.74	0.44	0.94	1.02	
10							0.57				0.09	0.67	1.16	0.49	0.54	1.84	
11												0.13	0.89	1.45			
12													0.09	1.65			
Weighted $F$ $\geq 3$ rings	0.81	0.46	0.18	0.30	0.69	0.44	0.43	1.51	0.19	0.19	0.88	0.48	0.59	1.30	1.46	1.41	
Percentage fishing mortality	55	37	16	26	50	36	35	78	17	17	58	39	45	73	77	76	

These values of fishing mortality have been calculated on the assumption that natural mortality ( $M$ ) = 0.10 (10%) at all ages. Input  $F$  = 0.6 on all ages in 1978/79 (the last year for which catch in number data are available).

\*Inefficient estimates.

contributed an additional 70 t. The total catch, including by-catches taken during and after the main fishery for the season which ended in February 1979 was almost 81 t.

**1979/80** A new series of cohort analyses was carried out. These indicated a slightly higher level of fishing mortality in 1975/76 than that estimated a year previously, and even higher levels in 1976/77 and 1977/78 (Table 6) although the value for the latter season could not be taken as being completely reliable for reasons discussed above. A new stock in number for age groups 5 and over was calculated for the start of the 1978/79 fishery. The catches of these age groups in that fishery would have generated a fishing mortality of  $F$  = 0.6 (46%). Applying values of  $F$  = 0.8 to the recruits, to take account of the fact that the fishery was mainly directed at these herring, and of  $F$  = 0.6 to all other age groups gave an estimate of stock size before fishing commenced of only 132 t, while surviving adults at the time of spawning in March/April 1979 amounted to only 64 t. Fortunately, for once, it was possible to obtain an independent check on whether the fishing mortality values applied for 1978/79 were realistic or not.

During the spring of 1979 scientists of the Central Electricity Generating Board (CEGB), Research Division carried out a number of grab surveys on the Eagle Bank and in St Lawrence Bay aimed at obtaining an estimate of the total number of herring eggs laid, as part of a programme of research to assess the effect of the Bradwell Nuclear Power Station cooling system on the larval and juvenile population of Thames Estuary herring in the River Blackwater. Surveys of herring larvae were also conducted over a substantial part of the Thames Estuary. The results from these surveys indicated a total egg production in the northern part of the Thames Estuary of about  $7.7 \times 10^9$  eggs (Dempsey and

Bamber, 1980). The MAFF biological sampling programme showed that a mean fecundity of 31 000 eggs per female was appropriate for the 1979 spawning season so that, on the basis of a 50:50 split between males and females in the stock,  $7.7 \times 10^9$  eggs was representative of a spawning population of 499 000 herring (60 t). Applying values of  $F$  = 0.8 on recruits and  $F$  = 0.6 on the older herring for the 1978/79 fishery, the total number of herring left at time of spawning in 1979 within the whole of the Thames Estuary would have been about 509 000 fish. Taking the proportion of those spawning in the northern part of the estuary at 70.7%, from the results of the 1977/78 tagging experiment, the number spawning in that part of the estuary in 1979 would have been 360 000 fish (45 t). \* There is thus a reasonable measure of agreement between the two estimates of the size of the spawning stock in the northern part of the Thames Estuary in 1979 and it may be concluded that the above values of fishing mortality for the 1978/79 fishery were sound. The same is true of the estimated 73 t of adult surviving stock left at the beginning of the winter of 1979/80.

With such a small surviving stock it was impossible to advocate any fishery in 1979/80 unless recruitment by the 1977 year-class turned out to be exceptionally strong. A fishing survey of the Thames Estuary was therefore carried out by RV NUCELLA during October and November 1979 in order to assess the strength of that year-class. A total of 32 shots was made with a fleet of driftnets in many localities throughout the Thames Estuary (Figure 12) but catches were very poor in all of them. Although herring of the 1977 year-class made up about 50% of all the herring

\* The estimate from the most recent VPA is in fact 424 000 fish (51 t).

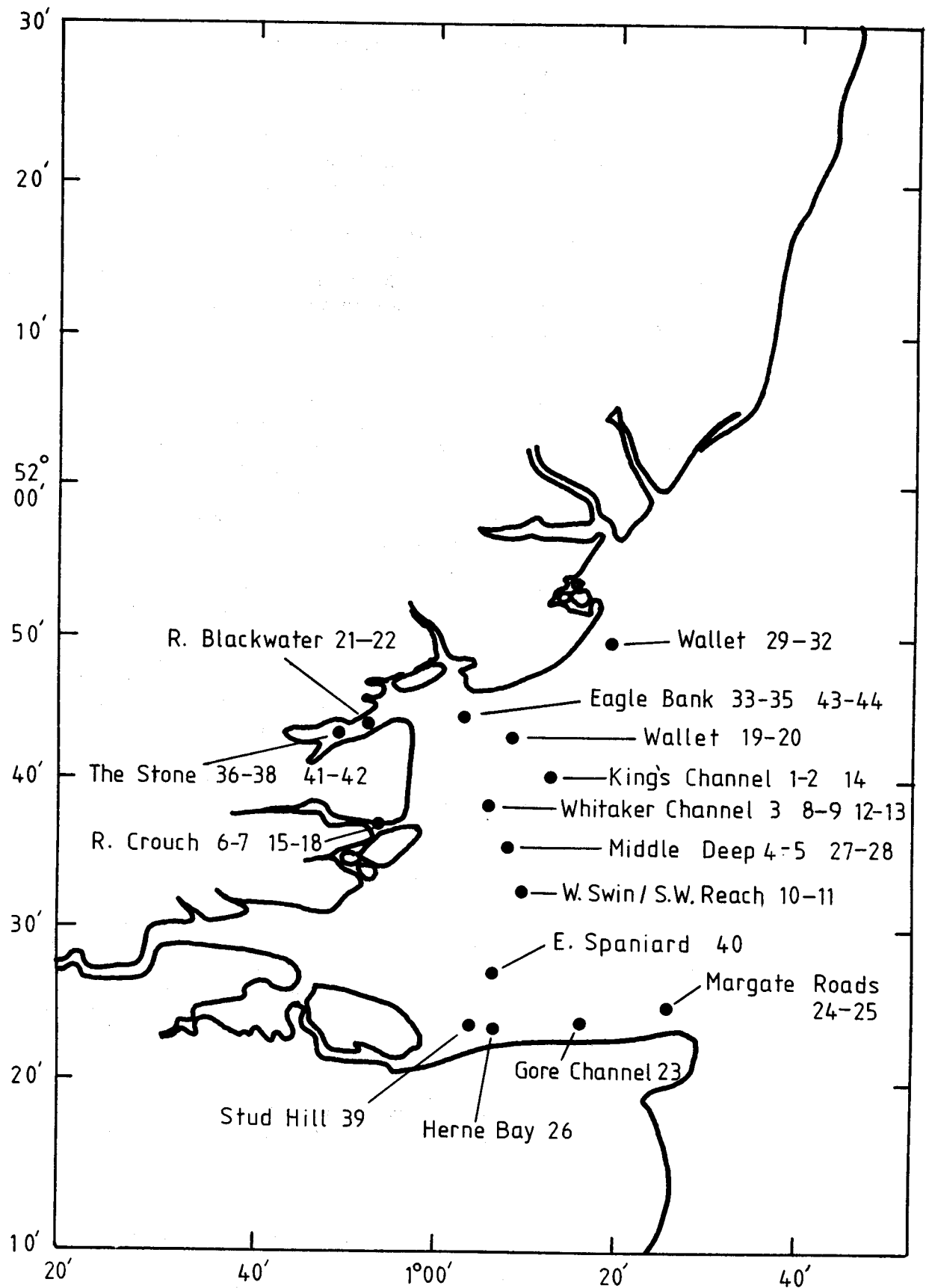


Figure 12 Fishing positions and haul reference numbers for RV NUCELLA surveys: October-November 1979 (1-32), March-April 1980 (33-44).

which were caught, indicating 528 000 3-year-old recruits in the stock, the estimated total spawning stock was only 127 t. In fact, as can be seen in Table 5, only two year-classes (1966 and 1967) have been recorded as weaker than the 1977 year-class since investigations commenced in 1962. Obviously, in the circumstances, no TAC could be recommended and the fishery remained closed throughout the winter of 1979/80.

In response to requests by Thames fishermen, further fishing was carried out by RV NUCELLA during March and April 1980 when the herring were concentrated for spawning. The catches taken confirmed both the original estimate of the weakness of the 1977 year-class and the small size of the spawning stock.

Sampling of herring larvae by CEBG scientists during April 1980 in the entrance to the River Blackwater resulted in somewhat higher numbers being caught than at the same time in 1979 (J. W. Whitehouse and P. A. Henderson, personal communications). This was consistent with an estimated increase in spawning stock of about 40 t for the northern part of the Thames Estuary in 1980.

*1980/81* A fishing survey of the Thames Estuary was again carried out by RV NUCELLA in October 1980. Thirty-three shots were made with a fleet of driftnets and all important localities were sampled at least twice. The results of this survey were most encouraging: catches of herring were substantially larger than in the previous year and included about 50% recruit herring of the 1978 year-class. Subsequent analysis of the catch and age data indicated a year-class strength of at least 1 million 3-year-olds and a total adult stock of about 240-280 t. The estimate of 240 t was obtained from the catches taken during the whole of the RV NUCELLA survey; the figure increased to 280 t if only the second half of the survey was considered, when recruits were represented in the catches in higher proportions, perhaps as a result of additional migration into the inner parts of the Thames Estuary during October. A TAC of 60 t was therefore proposed for the 1980/81 season, based on  $F = 0.3$  applied to the mean estimated adult stock in number of fish. This was the situation in December 1980 when fishing within the Thames Estuary was about to restart.

A summary of stock levels, TACs and annual catches for the six fishing seasons 1975-1981 is given in Table 7.

## 5. Future prospects

A major factor which had to be considered before any re-opening of the fishery could be advised was the minimum size of spawning stock at actual time of spawning necessary to ensure a reasonable chance of a good year-class being generated under normal circumstances. Below this critical level year-classes would become progressively weaker if the size of the spawning stock continued to decline, a stock/recruitment situation which should be avoided if at all possible.

In Figure 13 the size of the spawning stock of Thames Estuary herring for each year from 1963 to 1977 is plotted against the number of recruits which were produced (estimated at age 3-rings, i.e., about 2.5 years). A curve has been fitted to the data using the functional form proposed by Shepherd (1980). From this it is possible to calculate a value called the threshold biomass. When the biomass falls below this threshold value the curve tends to the straight line through the origin and the population is likely to collapse under exploitation. In the Thames Estuary herring stock the threshold biomass is about 220 t. The slope of the line passing from the 1970 point to the origin, i.e., the most optimistic assumption of recruitment at low stock levels which can be made, gives a value of 0.023 recruits/gram and it is most interesting that Shepherd (1980) obtained an identical value for North Sea herring.

It is clear, therefore, that the Thames Estuary herring spawning stock size should not be allowed to fall much below 220 t. A sensible management objective would be to build the size up to about 350 t, thus providing a buffer stock to offset the effects of poor recruitment.

The shape of the stock/recruitment curve in Figure 13 is somewhat unusual in that it is markedly dome-shaped. In the Thames Estuary stock very weak year-classes have been produced not only by very small spawning stocks but also by very large ones. The one exception was the 1968 year-class which was by far the strongest on record and originated

**Table 7 Thames Estuary herring: estimated adult stock size, TACs and recorded catches.**

Fishery	Adult stock size (t)		TAC set (t)	Recorded catch (t)
	First estimate	Latest estimate		
1975/76	600-800	474	None	339
1976/77	480-750	459	300	349
1977/78	540	261	190	196
1978/79	180-260	133	80	81
1979/80	122	122	Zero	Zero
1980/81	240-280	290	60	60

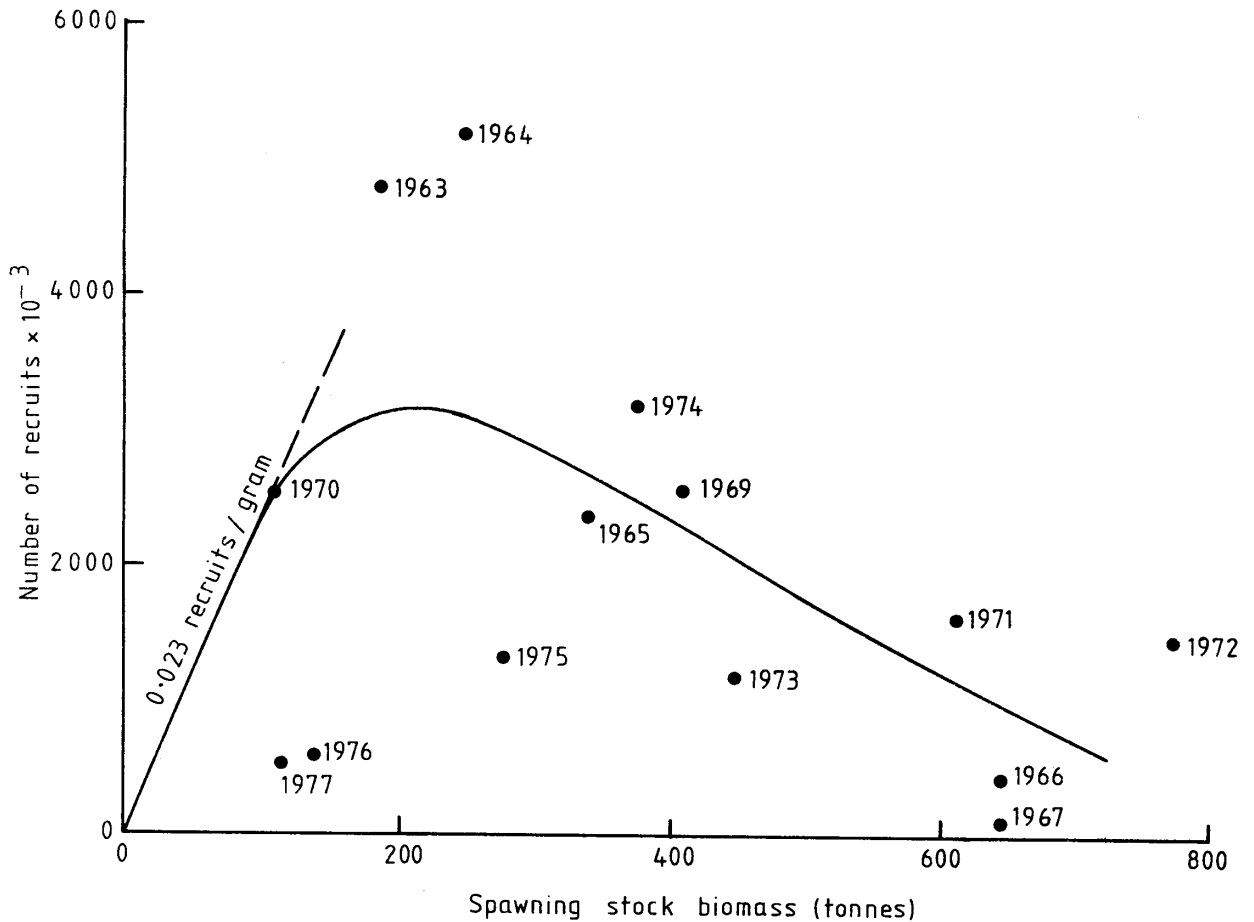


Figure 13 Thames Estuary herring: spawning stock biomass against subsequent recruitment numbers at age 3-rings (at 1 January).

from a spawning stock of about 570 t. Recruitment from a spawning stock smaller than about 80 t has not yet been measured but it is likely to be very poor. On the other hand, the very low level of recruitment from spawning stocks between 600 and 700 t was probably due to the oversaturation of the spawning beds with too many eggs. So far as is known, during those years (1966, 1967, 1971 and 1972) in which the spawning stock size exceeded 600 t, a very high proportion of all the herring of the Thames Estuary stock spawned on the Eagle Bank, at the entrance to the River Blackwater, so a layer many eggs deep would probably have been deposited. It is known from experimental evidence (Outram and Humphreys, 1974; Galkina, 1971) that only eggs in approximately the upper three to seven layers would have been likely to have received an adequate supply of oxygen for normal development and hatching of the larvae to have occurred. The decomposition of dead eggs in lower layers could also have had a detrimental effect on both the live eggs and newly hatched larvae. There is one piece of supporting evidence for the above hypothesis. MAFF divers examined the Eagle Bank in April 1970,

a year in which the herring spawning stock size was only about 110 t, and found an egg layer on the crest of the bank some 17-20 eggs thick. Approximately 40% of the eggs which were collected in a number of samples from this patch were found to be dead, presumably through oxygen starvation.

It would therefore appear that the Thames Estuary herring stock ought to be regulated in such a way as to ensure an adult stock at time of spawning within the range 200-400 t. However, these values could, due to the marked increase recently in the importance of the Herne Bay spawning grounds, possibly require revision at some future date. As already pointed out, the results of the 1977/78 tagging experiment indicated that approximately 29% of the Thames Estuary herring were spawning in the Herne Bay area in March 1978. In addition, in the recent seasons (1977/78, 1978/79 and 1979/80) O-group herring became much more abundant than previously in the lower reaches of the River Thames. These fish would be more likely to have originated from the Herne Bay spawning grounds rather than from the

Eagle Bank or from 'The Stone.' A more equitable division of stock between the two main areas in the northern and southern parts of the Thames Estuary could possibly lead to better egg and larvae survival than in earlier years when the Eagle Bank appeared to be of paramount importance.

The apparent increase in the size of the Herne Bay spawning component of the Thames Estuary stock could be related to the cleaning up of the River Thames. This might have resulted in a far better survival of larval and juvenile fish in the area, due to the dramatic reduction in pollution of the water. The increase in importance of this part of the stock poses the question: should the two spawning areas be managed separately? The answer must be no, unless fishing were to be confined only to the spawning areas just prior to and at spawning time. In the winter months, from October to January or early February, herring of both spawning components are mixed together throughout the estuary, being particularly concentrated in such localities as South-west Reach, Middle Deep and the East Swin. Only as spawning time approaches in February-March do the majority of the fish tend to separate and concentrate in their own individual spawning areas.

In turning to the immediate prospects, at a time when the spawning stock is small and the fishery within the Thames Estuary restricted to a low TAC, it is important to consider whether some fishing mortality is exerted on the stock elsewhere, such as in the Southern Bight. There is very little evidence indeed to suggest that this is so. Over the years only four herring which were tagged within the Thames Estuary have been returned from vessels fishing in the central and southern North Sea, and these fish might all have been members of the North Sea stock. It seems reasonable, therefore, to assume that any fishing mortality generated outside the Thames Estuary is insignificant.

The adult stock before fishing in the winter of 1980/81 was estimated at between 240 and 280 t and a TAC of 60 t was recommended. Although the recorded catch did not exceed this figure it is known that illegal fishing took place on both sides of the Thames Estuary prior to the opening of the fishery on 18 December 1980. In addition, several substantial by-catches of herring were taken by vessels engaged in the winter sprat fishery. Some of these may have been dumped at sea but a few were landed even though the by-catch level was far in excess of that legally permitted (i.e., 10% by weight). The actual catch of Thames Estuary herring which was taken during the 1980/81 fishery is therefore not known. Only time will show whether it was large enough to have seriously set back the recovery of this stock. It can only be hoped that the spawning stock size in March 1981 was not too far below the optimum level aimed for when the TAC was set at 60 t. As has been pointed out, strong year-classes in the past have been common to both the Thames Estuary and North Sea herring stocks. The 1978/79 year-class appears to be a strong one in the southern spawning component of the North Sea stock and O-group Thames Estuary herring of this year-class were very well represented in the whitebait catches at Southend during the winter of 1979/80. There seems therefore to be

a good chance that recruitment to the Thames Estuary stock in 1981/82 will be at such a level as to allow both a reasonable level of TAC and a continued rebuilding of the adult stock towards the required size of about 350 t.

#### Acknowledgement

The author wishes to record his appreciation of help received in the compilation of this report from his colleagues T. W. Boon and S. Warnes who assisted with both the preparation of data and the illustrations.

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