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THE BASS

(Dicentrarchus labrax)
and management of its fishery in England and Wales

BY: M.G. Pawson and G.D. Pickett

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FOREWORD

Increasing competition between sport anglers and commercial fishermen for bass stocks around Britain has resulted in overexploitation in some areas and fears for the species' future. There is a legal minimum landing size for bass in England and Wales, but, unfortunately, this has not provided the intended level of protection for juvenile fish which command a high market price in Europe. Since 1981, the Lowestoft laboratory has run a programme of research on the bass and its fishery, aimed at providing advice to the Government on the state of bass stocks and the management measures needed to safeguard their future and to maintain a fishery. This information was presented in a report to Ministers, and in July 1986 this was made available to representatives of those with an interest in the bass fishery. This leaflet has been prepared with a much wider audience in mind, though the use of some technical terms is difficult to avoid, particularly in Sections 4, 5 and 6 which deal with the assessment of bass stocks, the effects of the fishery on them and the rationale behind the management proposals.

A glossary of terms is appended (Appendix 1), and those seeking a more thorough understanding of the scientific basis for fisheries management are recommended to read MAFF Laboratory Leaflet No. 54 - "Background to Scientific Advice on Fisheries Management" by J. G. Pope.

A. Preston
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Laboratory Leaflet Number 59

THE BASS (*Dicentrarchus labrax*) AND MANAGEMENT OF ITS FISHERY IN ENGLAND AND WALES

by M. G. Pawson and G. D. Pickett

1. INTRODUCTION

The European bass, *Dicentrarchus labrax* (L.), is exploited commercially throughout most of its geographical range, which extends from the Mediterranean, along the Atlantic coast north from Morocco to Ireland in the north-west and to Norway in the north-east. It has also been a favourite quarry of sport anglers for over a century, but declining catches, which have been particularly noticeable on the west coast of Britain and in Eire since the 1950s (Kelley, 1979), have led anglers and conservationists to request governments to investigate the cause and, if possible, to provide remedial measures. Studies by Kennedy and Fitzmaurice (1972) in Eire and by Holden and Williams (1974) in England and Wales provided sufficient knowledge of the biology of the bass to enable precautionary conservation measures to be recommended. A minimum landing size (MLS) of 26 cm total length (the linear dimension used throughout this leaflet) was introduced in Great Britain in 1976 and 38 cm in Eire in 1975, though the latter lapsed after 2 years.

Since the mid-1970s, the bass has become one of the main target species for the inshore commercial fishery in southern Britain. Strong home and continental markets have ensured that high prices - comparable with those of other prime fish such as salmon, turbot and sole - are paid for bass, and pressure on the stocks has become intense. Renewed calls for a halt to the apparent decline of the British bass population resulted in MAFF's decision to increase the MLS to 32 cm* in May 1981 and to initiate an investigation of the bass fishery in England and Wales and of the species' biology, in order to provide the scientific basis for further management measures should they be considered necessary. This leaflet presents the results of this work and discusses how the bass fishery could be managed to safeguard the stocks and provide a high, sustainable yield. Where relevant information is available in scientific papers, these are referred to in the text.

2. THE BASS FISHERY

2.1 Landings and market

The officially recorded landings of bass in England and Wales rose from 21 t in 1972 to 234 t in 1983 and fell to 106 t in 1985 (MAFF, unpublished data). These MAFF statistics are based on landings at the main ports and do not cover all commercial outlets in a market which continues to expand. Very little account is taken of the contribution of part-time fishermen and anglers and the actual landings are considerably higher than those indicated by the official statistics. A national log-book scheme was introduced in 1983, and, since then, a representative sample of the participants in the whole bass fishery have continued to provide catch data throughout each year. The coverage of the fishery has improved each year and the scheme now permits a much more realistic estimate of landings to be made. The catches in 1983, 1984 and 1985 by fishing method and region are given in Table 1.

*The European Community has adopted an MLS for bass of 32 cm from 1 January 1987.

The official MAFF statistics represent a standard sample of the annual landings by the fishery and it appears that these peaked in 1983, though the figures in parentheses should be regarded as conservative estimates, since they are based only on landings for which we have firm data. By 1984, the log-book scheme was sufficiently well developed for catch estimates from then onwards to be comparable between years. Their relationship to the official MAFF statistics still varies from year to year, however, because it depends on the relative proportions of the catch taken by different gears in each region of the fishery.

Table 1 Bass landings (tonnes) by fishing method, 1983-85: official MAFF statistics (MAFF, unpublished data) with best estimates of actual landings in parentheses (+ values are below 0.1 t)

Fishing method	Region	1983	1984	1985
Beam trawl	East coast, Sussex, Hants, S. Devon	2.6	2.6	4.7
Otter trawl	East coast, Dorset, Devon, S. Wales	14.9	12.5	26.6
Pair trawl (bottom)	Thames Estuary, S. Devon & Cornwall	2.4	0.6	0.3
Pair trawl (midwater)	S. Devon & Cornwall	40.4	0.2	+
Midwater trawl	S. Devon	3.3	0.1	0.3
Trawl (unspecified)	East coast, Sussex, Devon, Cornwall	4.8	7.3	0.2
Danish fly seine	S. Devon & Cornwall	2.7	2.2	0.3
	TOTAL	70.9 (98.7)	25.2 (70.0)	32.4 (64.5)
Beach seine	Suffolk, S. Cornwall N. Wales	3.0	+	+
Drift net	Suffolk, Thames Estuary, Morecambe Bay	5.6	0.1 (115.7)	0.1 (5.1)
Gill net	All areas	63.1	52.7 (306.5)	36.3 (69.8)
	TOTAL	71.7 (271.0)	52.8 (422.2)	36.4 (74.9)
Tangle net	E. Kent, W. Cornwall	2.6	1.2	0.5
Stake net	S. Wales to Border	0.8	1.5	0.1
Trammel net	East coast, Kent, IOW, Devon, N. Wales	29.0	12.4	6.1 (38.4)
	TOTAL	32.4 (78.0)	15.2 (34.7)	6.7 (39.0)
Hand lines (including rod and line)	All areas TOTAL	56.3 (180.6)	42.8 (749.4)	27.8 (341.1)
Long-lines	S. Kent, Sussex, Hants, Cornwall	1.8	2.0 (40.3)	2.1 (46.3)
Pots	Cardigan Bay	0.8	+	+
	TOTAL	2.6 (16.2)	2.0 (40.3)	2.1 (46.3)
	GRAND TOTAL	234.0 (644.5)	138.1 (1316.6)	105.8 (565.8)

The main British market is to the hotel and restaurant trade, either directly from fishermen and merchants or via Billingsgate, London. There is also a vigorous export trade to France, Belgium, Italy and Spain, and demand has grown to such an extent that the average annual unit price has risen from 70p in 1972 to over £5.00 per kg in 1985, with prices of up to £10.00 per kg being reported when catches are low. At such times, Britain imports bass from continental Europe.

2.2 Bass behaviour and methods of capture

Bass are lively predators taking fish, crustaceans and marine worms at any depth in the water. They are known to favour particular feeding locations, such as rocky reefs and sand banks, where prey species are abundant, and may accumulate in areas with high densities of food, especially around shoals of small fish. Adult bass are also found in localities not directly connected with feeding, where they may congregate for spawning or just to rest. During the summer, the bass population tends to move into shallow water often very close inshore, and the fishes' movements and feeding patterns seem to be strongly affected by water temperature, tides, light intensity and wind strength and direction. This behaviour determines the methods used to catch bass and the distribution of the fishery, and, consequently, influences the information available on the distribution of the fish themselves.

Around Britain bass are usually caught within a few miles of the shore, being taken commercially from small (under 10 m) boats using a variety of methods, such as gill nets (fixed and drifted), trolled lures (on a fixed line behind a moving boat), and long-lines and from the shore by beach seines and set nets. They are also caught in an increasingly directed fishery by bigger vessels using trawls and seines, particularly in winter, and gill nets throughout the year. Most bass, however, are caught by rod and line, both for sport and by commercial fishermen. A substantial but indeterminate part of the sport catch is also sold and not recorded by MAFF. Any management measures introduced for the purpose of controlling bass mortality must, therefore, not only take into account the wide variety of fishing methods used to catch them, but also the fragmented and opportunistic nature of a fishery which is also prosecuted by anglers. Such measures must be simple, enforceable and fair.

2.3 Distribution and seasonality of the fishery

Figure 1 shows the estimated commercial bass landings by method for the International Council for the Exploration of the Sea (ICES) Fishing Areas around England and Wales during the 4 quarters of 1984. Bass catches are taken throughout the year in the English Channel, whereas at the northern limits of the bass's range, in the Solway Firth for instance, the main fishing season is in July or August. Few bass are caught inshore in winter, other than when the weather permits fishing by small boats on the reefs around Cornwall and off the coasts of Dorset and Hampshire, although French pair-trawlers and some UK vessels take adult bass in the western and central English Channel outside the UK 6-mile zone between January and May. Until the closure of the 'mackerel box' in 1983, large catches were also taken in the western English Channel in mid-water trawls and purse seines. During April bass begin to appear in the Solent, off north Cornwall and Devon, around south Wales and occasionally in the Thames Estuary, and fisheries in the Solent, south Wales and the Thames reach a peak through May and June.

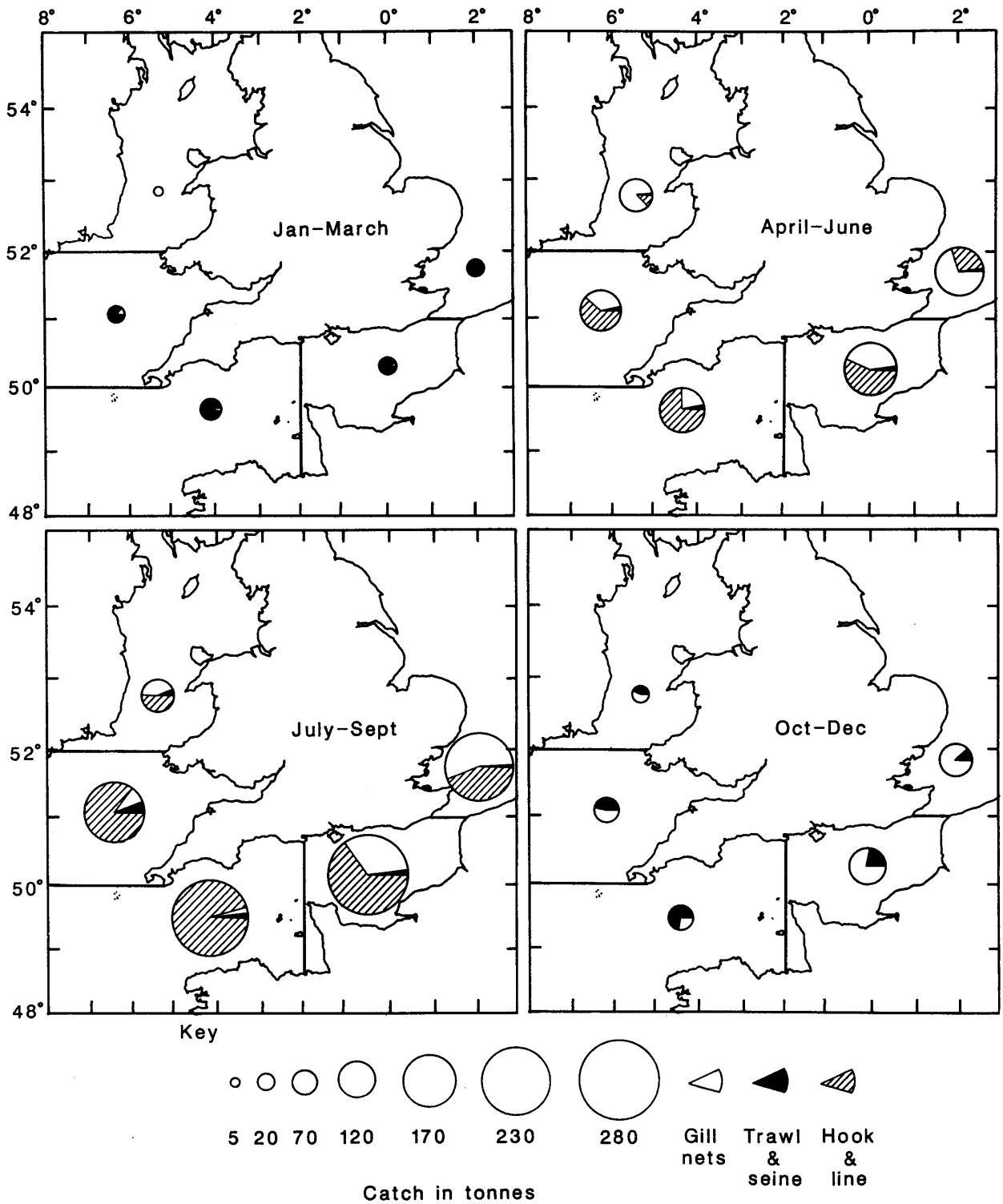

Figure 1 Bass catches by UK vessels in each of the ICES Fishing Areas bordering England and Wales during the 4 quarters of 1984.

There is often a decline in landings during July and August in these areas, although they usually increase again during September and October as the bass begin to return to the 'wintering' areas. The fishery generally ceases by the end of November, with the exception of around Cornwall and off Hampshire.

2.4 Regional characteristics

Exploited fish populations are conventionally managed on the basis of 'stocks'. These are units within a population which can be identified, which are usually prosecuted by distinct fisheries, and which can, for management purposes, be considered discrete. Whilst it is inferred that fish do not move between such stocks, this is not an essential assumption. Consequently, the UK bass fishery has been split into five main regions, each characterised by its fishing pattern rather than by the integrity of its bass population.

2.4.1 The east coast and Thames Estuary

Bass are occasionally caught in trawls as far north as Scarborough and in most summers small numbers are taken in salmon nets in Northumberland, where anglers also catch bass near warm-water outfalls from power stations, e.g. Blyth. The main commercial effort, however, usually occurs south of Aldeburgh in Suffolk. All methods except trolling are used to take bass of all sizes up to 25 miles offshore, often near sand banks. This is an important charter angling area, and rod and line and drifted and fixed gill nets probably account for the majority of the fish offered for sale.

2.4.2 The eastern Channel to Selsey

Commercial bass fishing activity in this region is largely of a part-time nature using gill and trammel nets. Because the majority of the participating boats are small and set nets close inshore for mullet, a high proportion of the bass in their catches tends to be small fish under 40 cm. Large bass are taken by angling near wrecks and over rough ground, and the bigger boats from east Kent, Worthing and Shoreham are beginning to exploit these fish commercially with gill nets and trawls. In 1983 a long-line fishery was established which has continued to make good landings of large bass in the west of the region.

2.4.3 The Solent and Dorset

Rod and line catches account for the majority of landings by both commercial boats and anglers, and much of the latter's catch is sold. Gill netting, however, probably produces the largest catches of small bass, and these are taken in trawls throughout the year. Long-lining is also important in the Solent, particularly in summer for adult bass, which are also taken in the Portland area on hooks. Otherwise few fish in the catches exceed 45 cm.

2.4.4 Devon and Cornwall

Small bass are taken by rod and line, gill nets and beach seines in estuaries and along some sheltered shorelines, and there is a seasonal fishery which takes larger fish (over 40 cm) by trolling and line fishing in tide runs and around reefs. When the weather permits, gill-netters take bass along the north Cornish coast between October and February. Incidental landings of adult bass are made by trawlers and seiners in both summer and winter, fishing up to 30 miles offshore.

2.4.5 South Wales to the Solway Firth

This is traditionally a sport angling area although gill nets, rod and line and occasionally trawls (in Carmarthen and Swansea Bays) are used to take fish of all sizes in an increasingly important commercial fishery. Because gill nets to the south and north of St Dogmaels are subject to local Sea Fisheries Committee (SFC) minimum mesh size (MMS) limits, of 100 and 89 mm respectively, bass under 35 cm are seldom caught there by this method. Bass fishing sometimes continues throughout the winter as far north as New Quay in Dyfed.

2.5 The international offshore fishery

When French landing statistics were made available to MAFF in 1982, we became aware that large (by British standards) catches of bass were being taken offshore in the western English Channel in late winter and spring by French pair trawlers. Several adult bass which had been tagged in the Thames Estuary were subsequently recaptured in this fishery, and this confirmed that the bass population being fished by English boats in the southern North Sea is, in fact, a shared stock. But apart from reports of two large bass tagged in western Britain being recaptured in the Bay of Biscay, there is no other firm evidence that the rest of the bass population which is caught inshore around England and Wales, is exploited to any significant extent by other countries' vessels.

2.6 Size composition of the fished stock

Data on the length distributions of bass in catches have been obtained from commercial fisheries and during tagging exercises around England and Wales; some examples are presented in Table 2. Fish caught by hooks can be

Table 2 Length distributions of bass taken in various English and Welsh fisheries

Total length (cm)	Thames Estuary	Solent		Portland Bill race	Devon and Cornwall								Carmarthen Bay	Morecambe Bay
	All methods	Small mesh trawl	Gill net (83 mm)	Rod and line	Estuary, gill nets (60-70 mm)	Inshore rod and line	Inshore reefs, lines	Offshore		Eddystone reef			Trawl	Gill nets (92 mm)
								Rod and line	Gill nets (~ 100 mm)	Trawl and seine	Lines	Gill nets (125 mm)		
	1983	1981-86	1981-84	1983	1980	1970-83	1980-83	1970-71	1981-83	1983-84	1980	1980	1982	1982/83
under 20		669				1								
20-22		244												
22-24	2	456			4									
24-26		754			26	8								
26-28		814			56	10								
28-30	3	1013			42	17			1					
30-32	3	462	25		28	38				1				1
32-34	2	264	96		12	67		7	1	3			15	5
34-36	9	273	204		6	43		9	1	9			55	29
36-38	8	142	228		3	19			6	7			112	109
38-40	9	74	126		3	38	8	29	11	7			98	142
40-42	20	59	34			55	8	56	27	8			57	135
42-44	38	35	14			13	38	5	30	22	1		42	96
44-46	36	16	8			23	49	45	52	55			17	33
46-48	45	12	5	1		22	48	26	73	133			19	11
48-50	33	9	2			14	67	16	61	90	3	1	16	2
50-52	31	3		5		9	59	12	50	126	3		21	1
52-54	20	1		8		2	50		25	93	3	6	7	4
54-56	14	1	1	8		16	35	10	22	93	5	7	5	1
56-58	14			21		5	39	9	9	46	4	21	5	
58-60	12			16		1	33	2	13	35	14	39	3	
60-62	1	2		17		2	14	10	5	22	16	38	4	
62-64	3	1		19		3	9	5	5	21	20	34	3	1
64-66	4			11		3	10	4	5	8	24	26	2	
66-68	4			12		4	5		4	11	29	17	1	
68-70	2			13		1	7		2	14	17	13	2	
over 70	11			16		1	7	1	6	18	51	11	1	

considered to represent the bass population in the fishing area at the time of sampling. Where commercial trawls have been used, it is assumed that they had a mesh size of at least 75 mm (the legal minimum) and would therefore have caught few bass under 30 cm. The small-meshed trawls used in MAFF surveys in the Solent catch bass down to 15 cm in length. The relatively slow towing speed of small inshore trawlers also reduces the probability of large (say over 50 cm) fast-swimming bass being taken. A similar, but more marked mesh selection of fish size also applies to bass caught in gill nets, including an additional selection against fish too large to become enmeshed (see Sub-section 6.2). The appearance of regional differences in size distributions is therefore probably due as much to the fishing methods used and the fishing pattern with regards to estuarine, inshore and offshore waters, as to real geographical differences in the range of juvenile and adult fish.

In general, bass in tidal rivers and estuaries tend to be less than 35 cm in length, and fish of this size are seldom encountered along rocky coastlines with no sheltered water, or around offshore sand banks and reefs where larger fish predominate. Bass over 50 cm are found inshore in the warmer months all around the English and Welsh coasts from Norfolk to the Solway Firth, especially in areas of fast tidal races (e.g. Portland Bill, Manacles, Runnel Stone, Worms Head and Menai Strait). For much of the year the larger fish occur in situations where their behaviour makes them much less susceptible to capture than the smaller bass close inshore. It is probable that they are present in the deeper water throughout the English and Bristol Channels in winter and spring and further north during summer and autumn, in many areas where they are not fished for or can avoid capture. The frequency of large bass in catches therefore underestimates their relative abundance in the population. The distribution of medium-sized fish of 35 to 50 cm is much less predictable and they may appear anywhere in the species' range. Bass under 20 cm are probably only present in estuaries and sheltered coastal waters where viable eggs and larvae have penetrated; their range extends further north following warm, early springs and summers, and retracts southwards after prolonged cold winters.

3. BIOLOGY

3.1 Life history

Bass reach maturity at 4-6 years of age (~ 35-40 cm) and may continue to spawn for up to 20 years thereafter. Ripening males can be found from mid-November in the western English Channel until May or June around Wales (and probably off East Anglia), but ripe females are less often reported in catches, possibly due to the much briefer period during which they are ready to spawn. The main spawning season extends from March in the western English Channel until June off north Wales and in the southern North Sea.

Bass eggs have been sorted from plankton samples taken by MAFF research vessels during cruises in the English Channel since 1981, and typical distributions at intervals during the spawning season are shown in Figure 2 (from Thompson and Harrop, 1987). The eggs were found at all depths in the water. Spawning appeared to have commenced well offshore in February and, except in the vicinity of the main headlands, continued chiefly outside the English 12-mile zone in March and April. Eggs appeared closer inshore in May and June, though the centre of spawning was still probably 3 miles or more offshore. The spawning distribution of the west coast population is not so well known.

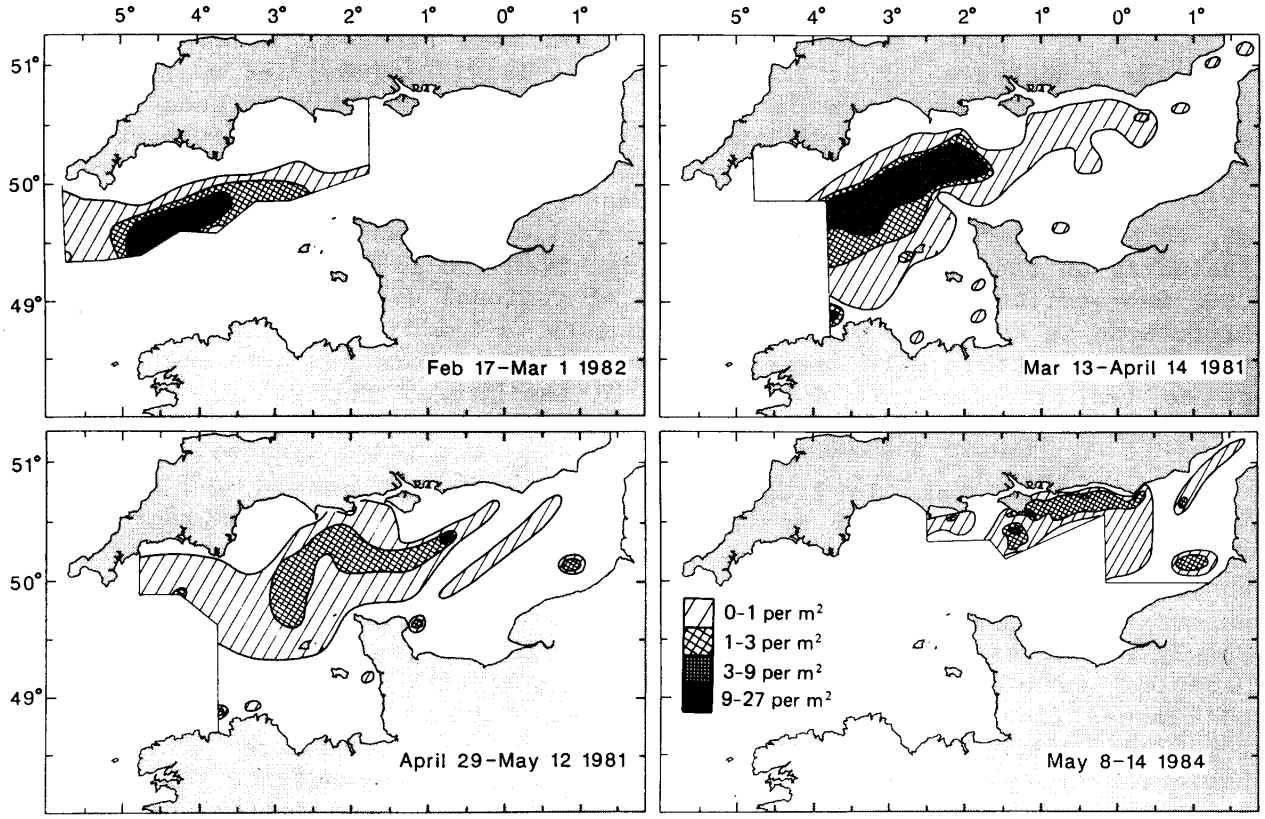

Figure 2 The distribution of bass eggs in the English Channel at intervals throughout the spawning season. From MAFF plankton surveys within the limits indicated by the straight lines (after Thompson and Harrop, 1987).

The larvae do not adopt a typical young bass lifestyle in the brackish water of estuaries until 2 or 3 months after hatching, and it is likely that the offshore spawning provides the post-larval bass of 15 mm upwards seen in estuaries in southern England in June/July and in Wales in July/August (Dando and Demir, 1985; Kelley, 1986). The mechanism by which larvae enter these nursery areas is not known, although some bass do spawn close inshore late in the season. As the 0-group bass grow they move progressively nearer to the mouths of estuaries, where they are found during the autumn and winter of their first year.

3.2 Growth

Most species of fish which live in waters with fluctuating temperature regimes have distinct seasonal patterns of growth. These result in structural patterns of their scales and otoliths (ear-stones), which can be used to age individual fish. A typical scale from the flank of a 5-year-old bass is shown in Figure 3; the indications of annual checks in growth, which occur chiefly between January and June, can clearly be seen. Because the distance from the scale's nucleus to each of these checks is proportional to the length of the fish at the time that the check was formed, the history of each fish's growth can be determined by scale-reading.

Juvenile bass generally grow slowly relative to many northern temperate roundfish species, reaching a length of approximately 33 cm (400 g, 0.9 lb) after 4 years and 41 cm (700 g, 1.5 lb) after 6 years. Differences in the

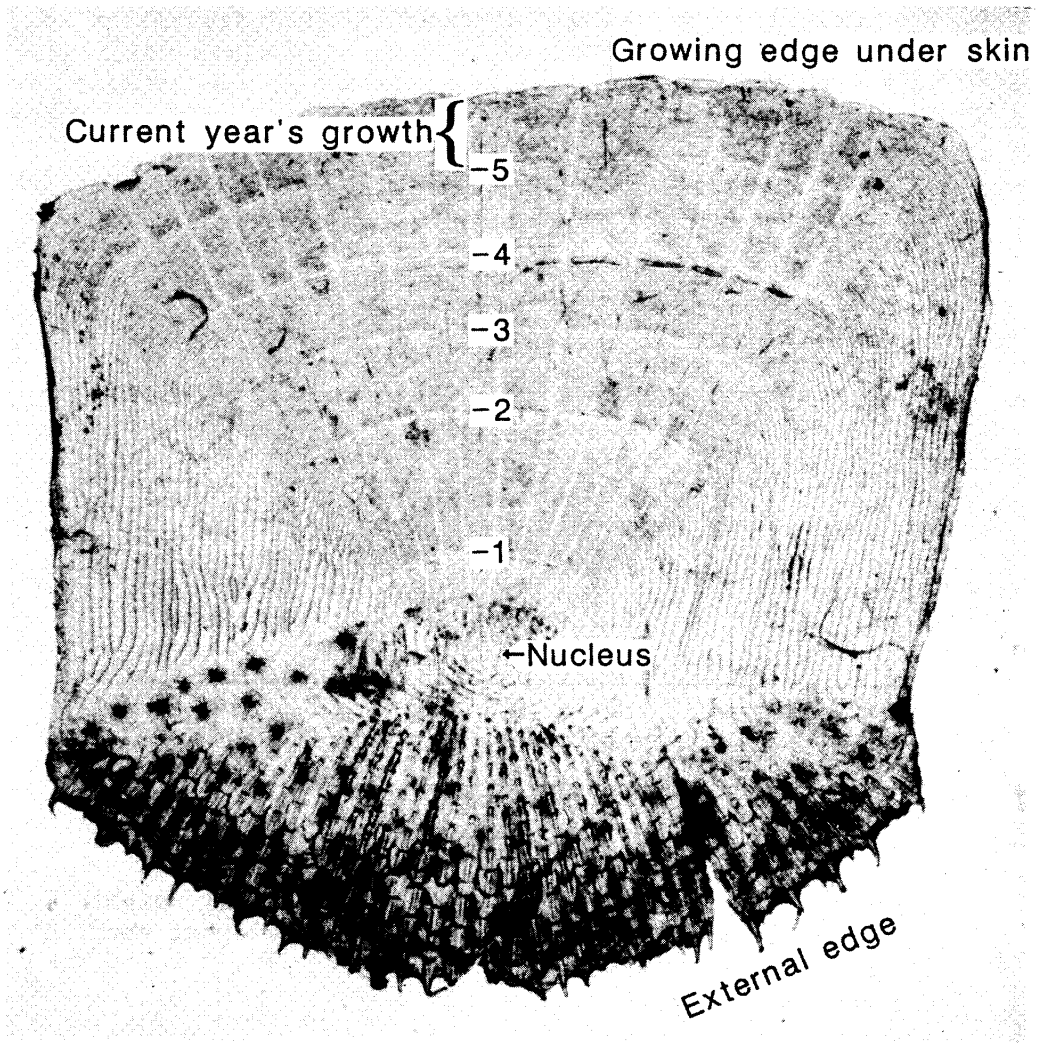

Figure 3 A scale from the flank of a 5-year-old bass caught in September, showing nucleus and annual checks.

growth of year classes have been observed; some of the 1979 brood, for example, exceeded 40 cm after 4 years. It is known that a warm summer will usually produce enhanced growth for that year and warm water conditions, such as cooling water outflows from power stations, provide high growth opportunities in some areas, notably in the Thames Estuary. Once bass mature, however, they increase steadily in weight (Figure 4) and there are several records of fish of over 9 kg (20 lb) being taken in the commercial fishery, including one of 9.7 kg (21.25 lb) in Chichester Harbour in 1984. The present rod-caught record stands at 8.35 kg (18.4 lb).

The lengths-at-age of bass taken in various fisheries around England and Wales are shown in Figure 5. It appears that growth rates are similar everywhere, though the bass taken inshore (shown by the dashed lines in Figure 5) tend to be the slowest growing part of the population. It is also noticeable that some faster growing adult fish are caught in varying proportions throughout the fishery in summer, particularly in the Thames Estuary. Tagging has shown that many bass which enter the fishery there from June onwards have spent winter and early spring offshore in the western English Channel. These fish will have experienced warmer temperatures and thus a longer growth season than fish which remain in the southern North Sea or

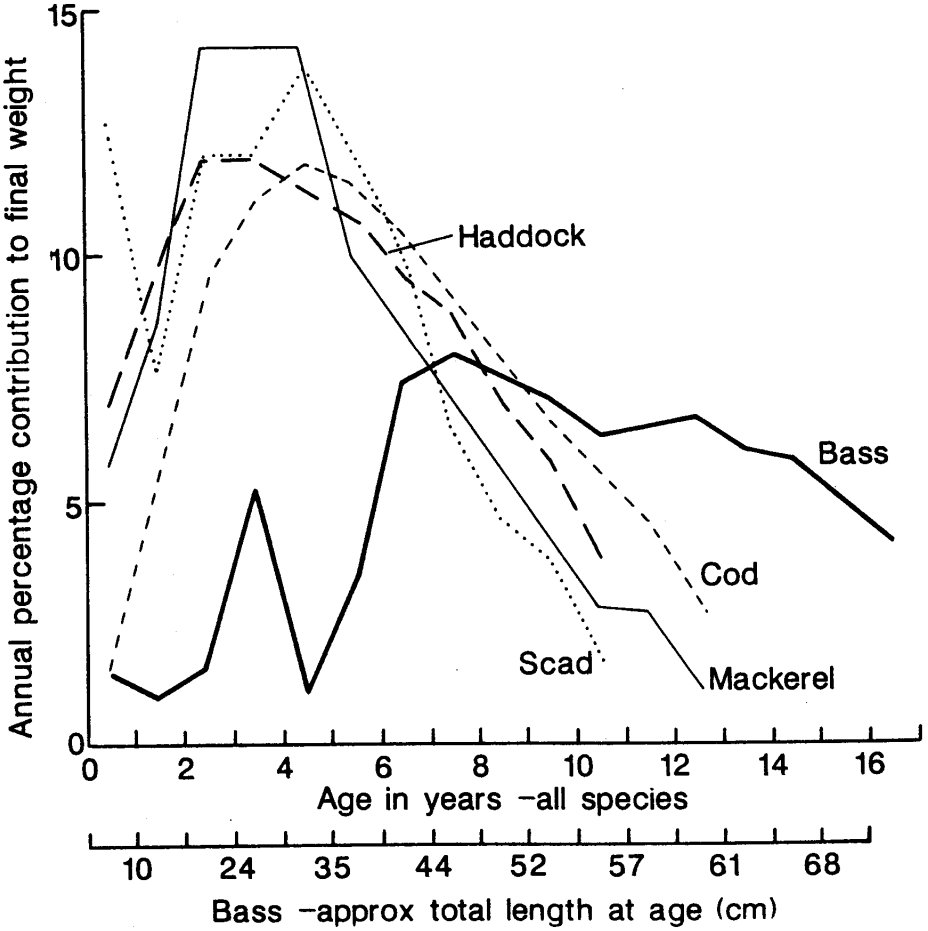

Figure 4 The annual contribution to the final weight in bass, compared with that of 4 other commercial species.

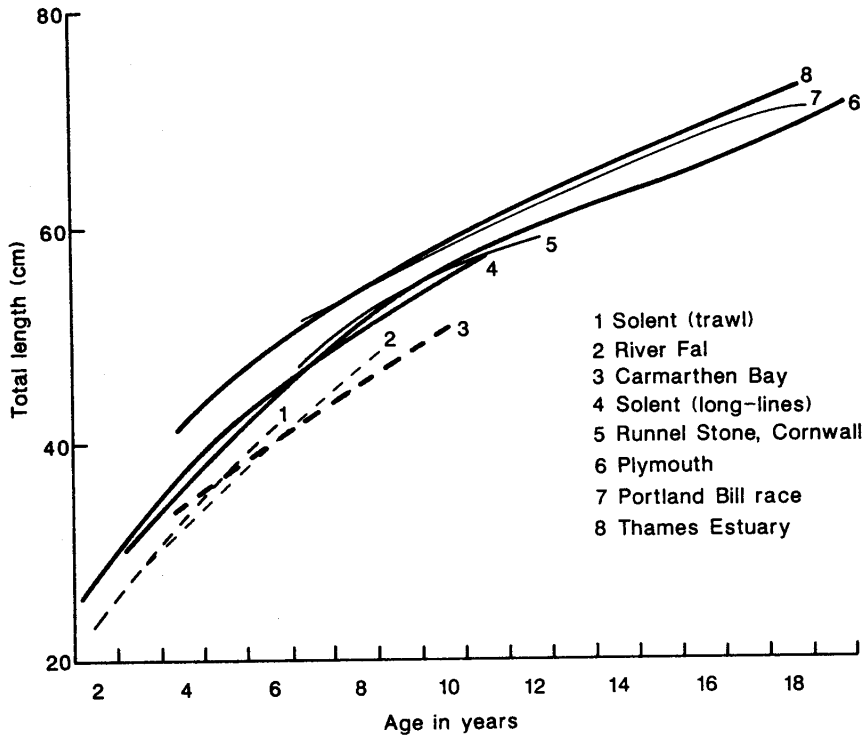

Figure 5 The growth in length of bass taken in various fisheries around England and Wales during the period 1982-85.

along the south-east English coast in the winter, and will tend to be larger at a particular age. This phenomenon, of seasonal immigration of bass from waters further south, occurs in most parts of the English and Welsh fisheries.

Male and female bass appear to grow at the same rate until they reach maturity, which happens, on average, one year earlier in males. Subsequently, females tend to be larger at a given age and for 4 or 5 years after maturing are usually heavier than males of the same length (Figure 6). The scarcity of males among bass of 5 kg upwards is probably due to their suffering a higher mortality rate than females once they become mature.

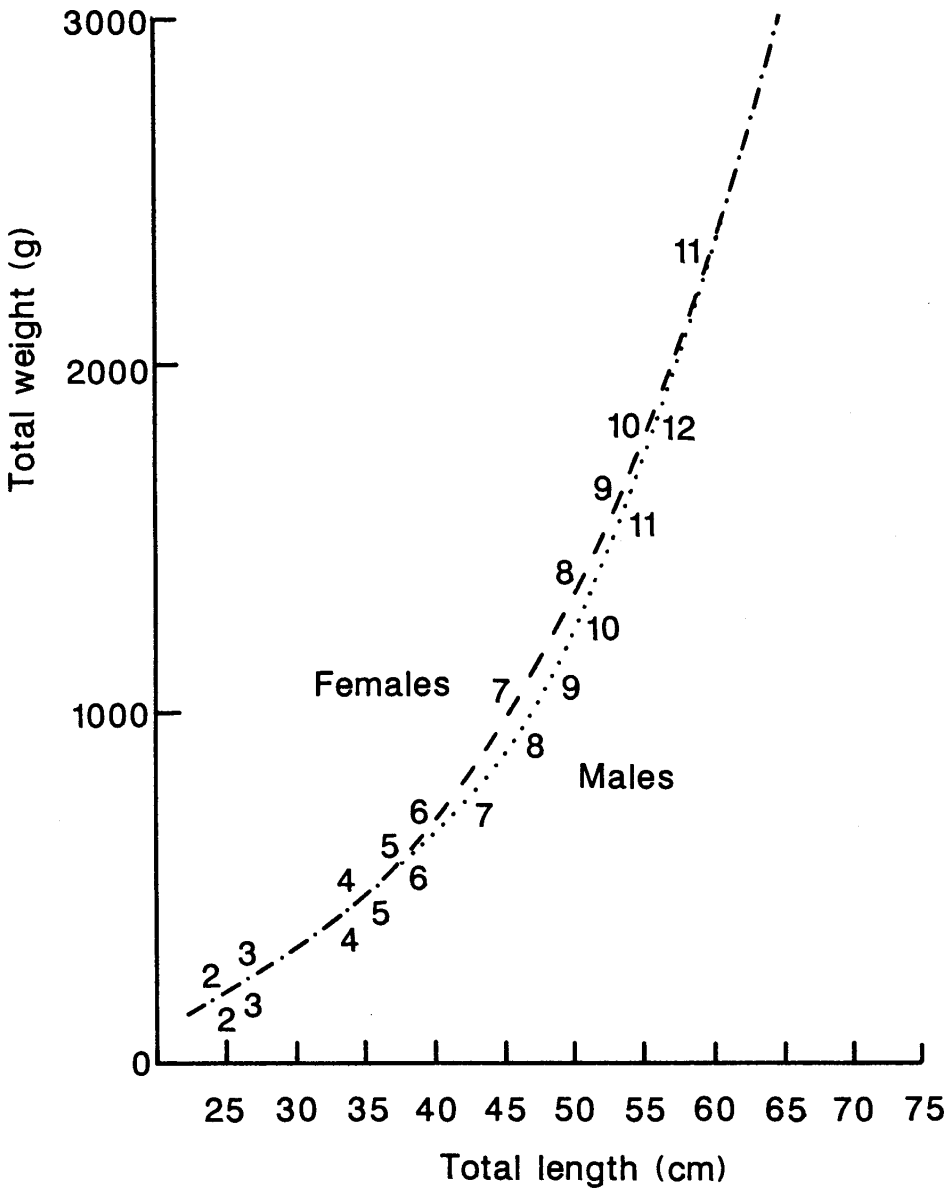

Figure 6 The relationship between length and weight of female (dashed line) and male (dotted line) bass caught in the UK fishery, with the ages at particular length-weight combinations shown above and below the curves respectively.

3.3 Migrations and stock identity

Bass have been tagged in England and Wales (Table 3) to discover the distribution and movements of the fished populations (Pawson, Kelley and Pickett, 1987). The majority of fish released were under 40 cm long, except in the earliest years of tagging at Anglesey, in the Thames Estuary, and at Portland Bill and Runnel Stone where adult bass were tagged off rocky headlands. Over 90% of recaptures were made within 2 years of tagging and tags have been returned from around 10% of all bass released during the period 1975-85.

Table 3 Release and recapture data of bass tagging exercises around England and Wales up to July 1986 (from Pawson *et al.*, 1987)

Release area	Tagging site	Release years	Tagging days and season	Catching method	Number tagged	Total released (number of adults)	Total recaptures		Annual recaptures		
							Number	%	Tagging year	Next year	Subsequent years
Thames Estuary	Bradwell coast, southern and outer estuary	1979-84	Σ195 days May-Nov	Rod and line (boat) Gill nets	764 78	842 (531)	92	10.9	32	34	26
Solent	Ryde Bay + Hayling Island	1971	Opportunistic	Rod and line (shore and boat)	183	183 (-)	2	1.1	2	0	0
	Chichester Harbour to Cowes	1981-84	Σ40 days Apr-Sep	Trawl Gill net Long-line	1 839 115 59	2 013 (85)	204	10.1	121	58	25
Portland	Portland Bill race	1983	4 days Jul	Lines	148	148 (148)	14	9.5	1	12	1
South Devon	Berry Head + Dart, Tamar and Teign Estuaries	1970-71	Opportunistic Jun-Oct	Rod and line Trawl	575 95	670 (240)	48	7.2	32	13	3
West Cornwall	Runnel Stone	1982	3 days Oct	Trolled lines	191	191 (191)	12	6.3	2	9	1
North Cornwall	Camel Estuary	1975-78	Σ71 days Mar-Nov	Beach seine Rod and line	46 132	178 (42)	32	18.0	17	14	1
	Camel Estuary + adjoining coast	1981-84	Σ58 days May-Oct	Rod and line	225	225 (3)	32	14.2	18	12	2
North Devon	Bude + Bideford Bay	1970-71	Opportunistic	Rod and line	101	101 (-)	15	14.9	13	1	1
Carmarthen Bay	Off Pembrey	1982	4 days Sep	Trawl Rod and line (boat)	181 10	191 (73)	4	2.1	0	3	1
North Pembroke	Nyfern and Teifi Estuaries	1979-81	Σ58 days May-Nov	Beach seine Rod and line	180 37	217 (42)	24	11.1	10	12	2
Anglesey	Coast between Aberffraw and Newborough	1971-75	Σ153 days Apr-Dec	Beach and seine Rod and line	792 120	912 (524)	86	9.4	33	45	8
		1984	Σ7 days Jun-Jul Σ13 days Oct-Dec	Beach seine Rod and line	41 21	62 (49)	11	17.7	3	6	2

The movements and interrelationships of different parts of the bass population around the English and Welsh coasts are illustrated by the results of these tagging exercises, which are summarised below.

3.3.1 The Thames Estuary

Thirty percent of the recaptures of bass tagged in the Thames Estuary were reported from within 5 miles of the tagging position, and 70% from within the estuary. Most of these fish were caught between April and October, though there were 6 recoveries in November and December near the warm-water outfall from Bradwell Power Station and 6 fish were recaptured off the east Kent coast between September and February. The remaining

recaptures were further afield with 3 fish being taken in the southern North Sea in spring and summer. In winter, 5 fish of around 35-40 cm were recaptured near the south coast between Newhaven and Poole and 13 larger bass were taken in the deep water in the English Channel west of Guernsey (11 fish) and off north-west France (2 fish).

It appears that the bass population being fished in the Thames Estuary is present there chiefly between May and October, inclusive, and that some fish travel throughout the southern North Sea. During the autumn the larger bass move towards the English Channel and, whilst some may not actually leave the North Sea, many fish of 30-40 cm move westwards along the English coast as far as Poole harbour, with a high proportion of the adults above 40 cm) reaching the western Channel well away from the English coast.

3.3.2 The Solent and Dorset

Very few recaptures of bass released in the Solent were reported more than 50 miles from the release position, 87% being recovered within the Solent itself. The results indicate that bass of 3 to 6 years old move through the Solent towards the west during the summer and autumn, and that most remain near, or return to, the same locality in subsequent summers. Although only 1 fish was reported from west of Poole in winter, several bass in the 30-40 cm range were recovered to the east of the Solent in late winter and spring. This suggests that a part of the population may move into the eastern Channel, and possibly the North Sea, following the route which Thames Estuary bass may take when returning from their wintering grounds. No adult bass tagged in the Solent, however, have been recaptured outside the release area.

Similar results were obtained with large bass tagged off Portland Bill in July 1983. Thirteen recaptures were reported during the summer: 11 at the tagging location, 1 in the east Solent, and 1 in Lyme Bay. The single winter recovery was off northern Spain, indicating that some large bass, which are found in summer at particular localities in the English Channel, may be seasonal migrants from much further south.

3.3.3 Devon and Cornwall

Of 670 bass released in summer around the south Devon coast, only 4 were recaptured more than 20 miles distant; 3 were caught off south Cornwall and 1 in Poole harbour. It appears that the few bass which do leave the area around Start Point move westwards during the summer, autumn and winter and possibly to the east in spring. It should be noted, however, that commercial bass fishing effort was low during the tagging period (1970/71) and that over 90% of tags were returned by anglers fishing inshore. Similarly, most (81%) of the recaptures of bass released on the north coasts of Devon and Cornwall were made in the tagging locality, though a few bass moved northwards as far as south-west Wales in summer. Six larger fish, which had been tagged near Land's End in October 1982, were also recaptured between June and August in the Bristol Channel, though reports of two others from Cumbria in August and September 1983 demonstrate that some adult bass will travel the whole of the west coast in a year (see Sub-section 3.3.4 below).

3.3.4 The west coast

The four tagging exercises on the coast of Wales will be considered together since they appear to involve the same bass population. Just under half of the recaptures of bass tagged at Anglesey were recorded within 5 miles of the release position, some during each month of the year. Fish which were caught at a greater distance in the year of tagging were taken either along the north Wales coast in August (3) or to the south in Cornish waters (6) in October and November. During subsequent years, tagged fish were reported from south of the release position only in the spring and autumn, whereas the majority (72%) of those which were recovered away from the tagging locality were taken in summer to the north, along the Lancashire and south Cumbrian coasts. All but 3 (tagged in May) of these fish were tagged in the autumn.

Two-thirds of the recaptures of bass tagged on the north Pembrokeshire coast were more than 5 miles from the release site. One fish tagged in June had travelled to Cumbria within a month and 4 autumn-tagged fish were also recaptured to the north, off mid-Wales. The main movement was to the south, however, with 3 fish tagged in late summer being reported off west Pembrokeshire within one month of tagging and 6 more being taken around Cornwall (5) and north Devon in the winter. These observations, of bass moving south along the Welsh coast in autumn and being caught off north Devon in January or from the south coasts of Devon and Cornwall subsequently, were also supported by the results of taggings in Carmarthen Bay in September 1982.

These studies show that a large proportion of the adult bass population on the west coast undergoes extensive migrations to the north and south each year. Those which occur around west and north Wales in summer may move as far south as the western English Channel in the autumn, whilst bass which are found near Anglesey in the autumn and spring do not appear to move so far south and are found to the north around Cumbria during the summer.

3.4 Dispersion by size

An examination of the recapture positions of tagged bass reveals that dispersion patterns differ between size groups (Table 4). Of all the bass

Table 4 The seasonal distributions of bass recaptures in relation to distance from the tagging site and distance from the shore (miles)

Tagging category	Recapture period												Total recaptures
	May-October			November-April			May-October			November-April			
	Distance along coast from tagging site (miles)						Distance offshore (miles)						
	0-10	10-50	50+	0-10	10-50	50+	0-3	3-12	12+	0-3	3-12	12+	
Juveniles (under 32 cm)													
tagged in summer	143	37	10	26	8	4	189	0	0	39	0	0	228
tagged in winter	18	2	0	11	3	4	19	1	0	18	0	0	38
Intermediates (32-42 cm)													
tagged in summer	51	30	8	19	9	10	71	16	1	35	2	2	127
tagged in winter	3	3	2	2	1	0	7	0	1	3	0	0	11
Adults (over 42 cm)													
tagged in summer	78	21	3	4	5	31	85	13	6	14	4	20	142
tagged in winter	6	6	15	9	3	2	27	0	0	12	0	2	41

tagged at under 32 cm, less than 5% of those recovered were more than 50 miles from the release position and only 2 were reported from a distance of more than 100 miles. For bass tagged at 32-42 cm, 20% of recaptures were reported more than 50 miles from the tagging site, and 14% were more than 100 miles distant. The distribution of recaptured bass tagged at over 42 cm follows the same trend, as 27% were taken over 50 miles from the release position and 23% were recaptured more than 100 miles away.

The tendency to remain in a particular area throughout the year appears to diminish as bass grow and the accompanying seasonal movements are more extensive in the larger fish. Most fish (75%), recovered during the same season of the year as that in which they were tagged, were caught within 10 miles of the release site. At the same time, the proportion recaptured at more than 50 miles distant was highest in the size range 32-42 cm (11.3%) and lowest with larger fish (2.5%), demonstrating that the latter show a strong attachment to specific areas at a particular season. In contrast, the proportion recaptured at more than 50 miles distant in the opposite season to that in which they were tagged rose with fish size (11% to 75%), a consequence of the seasonal migrations of adult bass.

3.5 Genetic infrastructure

Proteins from heart and liver tissues of juvenile bass sampled at 20 sites around Britain have been the subject of electrophoretic analysis to look for evidence of separate genetic races within the UK population. Out of 5 enzyme systems examined, only one (phosphoglucomutase) showed a statistically significant difference in its characteristics (in fish from mid-Wales, Solway Firth and Herne Bay) when compared with the total sample. The pattern of variation in these proteins, however, overlaps considerably those from most other sites, and there is therefore no evidence that bass sampled around Britain come from more than one genetic race.

3.6 Summary of distribution and movements

Because bass tagged at any one release site appear to follow a particular annual migration route, which may be characteristic of that group of fish, the distributions and movements of bass inferred from the recapture positions recorded for several separate tagging exercises are probably not representative of the whole population. We have therefore supplemented the tagging results presented above with information on the species' biology and the geographical and seasonal fishery patterns, in order to provide a more comprehensive picture of the migrations and distribution patterns for adult bass around Britain (Figure 7).

Bass up to 3 years old remain close inshore in spring and summer, usually in estuaries and even entering fresh water, and move into deeper water close by during the winter. As they approach maturity bass begin to leave these nursery areas and exhibit greater mobility, undergoing regular seasonal migrations eastwards and northwards as the water warms in spring and to the west and south as it cools in the autumn. These movements may be over 100 miles or more, particularly as the fish reach the ages (4-6 years) and sizes (35-40 cm) of first spawning. The proportion recaptured near the tagging site in subsequent years does not differ from that in the year of tagging, and it therefore seems probable that the fish use the same general summer feeding area during each of the first 4 or 5 years. Some bass of 32-42 cm, however, appear to have moved well away from the tagging locality and into areas where fish below and above this size range, tagged with them, were not found.

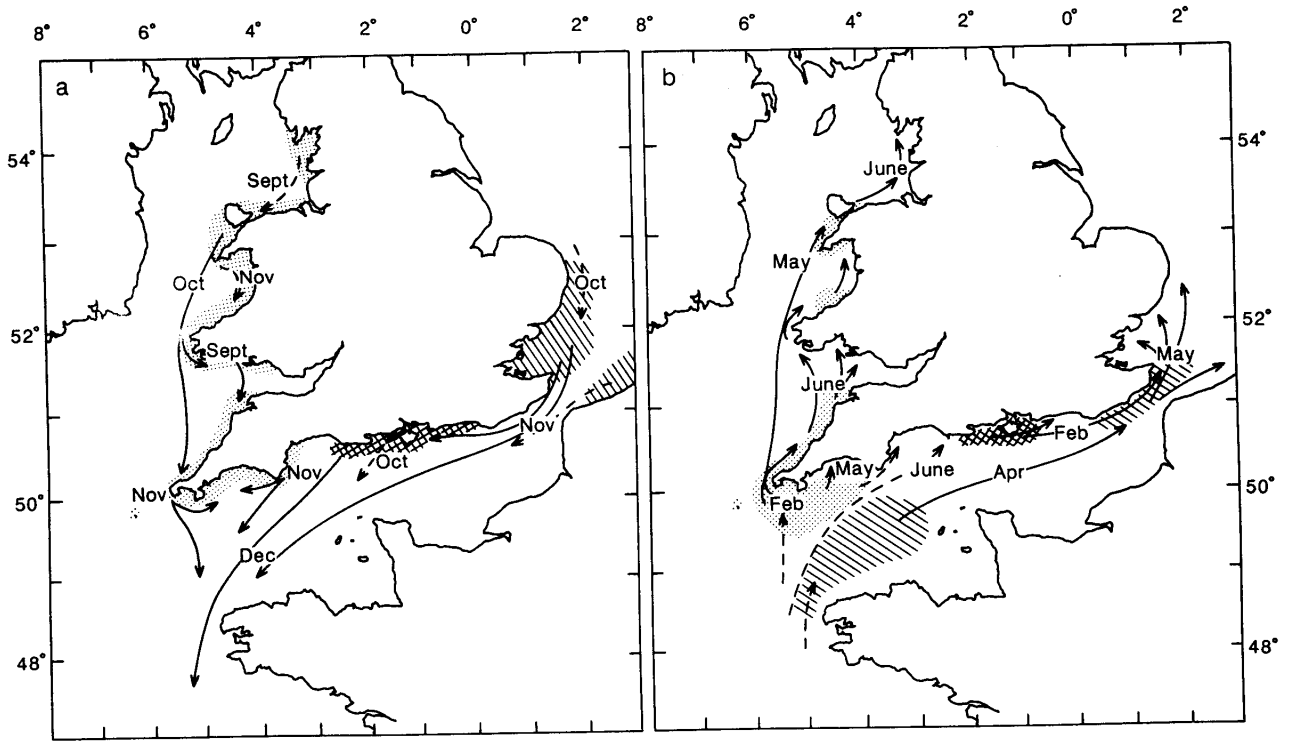

Figure 7 The seasonal movements and distributions of adult bass in the 3 main populations tagged around England and Wales, indicated by shaded areas: (a) autumn movements from summer areas; (b) late winter and spring movements from winter areas. Solid lines represent known movements, broken lines represent inferred movements.

Adult bass have been shown to make extensive migrations, some fish being recaptured in winter 200 or 300 miles to the south and/or west of a summer tagging site. Fish tagged in winter have been caught in summer a similar distance to the north of the tagging site. In both cases they usually return to the release area in subsequent years. Two main routes, which appear to be used by separate parts of the population, are indicated: between the English Channel west of Start Point in winter and the Thames Estuary and southern North Sea in summer; and from around the Devon and Cornwall peninsula in winter towards Wales and north-west England in summer. These migrations are to some extent modified by the weather; unseasonally warm conditions in Britain result in an earlier northward movement and a later return south, with bass being reported in greater quantities and further north than during a cold year. These factors may also influence the influx of bass from waters around mainland Europe into the UK and Eire fisheries, but as there does not appear to have been any tagging of bass outside the 12-mile zone around the British Isles, it is difficult to estimate the level at which this occurs.

Of 228 bass tagged at under 32 cm and later recaptured, only one has been reported more than 3 miles offshore. Fish above 42 cm from the English and Welsh populations regularly move outside the 6-mile zone; 29 out of 184 recaptures have been reported outside the UK 12-mile zone, chiefly by foreign vessels; three-quarters of these were tagged in the Thames Estuary.

It is significant, however, that returns of bass tagged in all areas have decreased rapidly after the year following tagging. This may be due to a high level of tag shedding or mortality by that time, but may also indicate that as the fish grow they spend more time away from the UK coast and are not being caught so readily by the UK fishery. Nevertheless, there appears to be little emigration of UK bass to the coastal populations of continental north-west Europe.

Tagging returns have often shown a higher recapture rate for adult bass than for juveniles, particularly from fish caught in the summer in the area of release, and this could be a consequence of adults following migration routes with greater precision than that shown by juveniles. Furthermore, tagging exercises have been carried out where bass can be caught readily, i.e. precisely those areas which attract the greatest bass fishing activity. The high return rates, therefore, do not necessarily indicate a higher exploitation rate on the adult population as a whole compared to that of juveniles. These observations might also explain how local declines in catches of large fish can occur in summer feeding areas where there is a high level of fishing activity, as has been seen, for example, in the Portland Bill race fishery in 1983-86. In such cases, the behaviourally 'isolated' adult population eventually dwindles and is only replenished as maturing fish enter the area and gradually re-establish an adult population. This is most likely to occur with a large year class. Despite the widespread publicity of bass tagging schemes, non-reporting of recaptured fish seriously devalues these data for assessment purposes.

4. ASSESSMENT OF BASS POPULATIONS

4.1 0-group abundance - power station intake screen samples

First-year (0-group) bass are regularly trapped on the screens of power station cooling water intakes in the autumn and winter in several localities, and their occurrence there has been used to estimate the relative strength of year classes. Table 5 gives the numbers of 0-group bass taken from the screens at West Thurrock (River Thames) and Oldbury (River Severn) for a standard volume of intake water from 1972 to 1986, where data are available. The relative abundance of each year class varies between sampling sites, due mainly to differences in the susceptibility of 0-group bass to the intakes, but also to regional differences in the brood strength. The high abundance of the 1976 year class could have been predicted from these data 3 or 4 years before it was seen that these fish were dominating the estuarine and coastal populations in 1980 and 1981. More recently, it appears that the 1981-83 spawnings were quite successful and the fishery should benefit from the resulting year classes, though from 1984 onwards only weak recruitment is indicated.

4.2 2-5-year-old bass abundance - fine mesh trawl surveys

Each year since 1981, we have used high lift bottom trawls fitted with fine mesh liners in the cod-end to monitor the abundance of 2-5-year-old bass in the Solent. The results given in Table 5 indicate that, in the Solent at least, the 1976, 1979, 1982 and 1983 year classes were large. An estimate of the relative abundance of each year class from 1976 onwards at comparable ages is shown in Figure 8. Considered together with the data presented for power station intake screen samples, it appears that at least 4 of the last 11 year classes (1976-86) have been of above average strength, and that 4 have been relative failures.

Table 5 Abundance indices of 0-group bass from power station intake screens (numbers/unit volume filtered), and year-group composition in Solent fine meshed trawl hauls (- = no data)

Year class	Power station intake screen samples		Fine meshed trawl samples, Solent							
			Catch (%)							
	East coast	West coast	Jun 1981	Apr 1982	Sep 1982	Sep 1983	May 1984	Sep 1984	Jul 1985	Sep 1986
1972	-	3	0.3	0.2	0	0	0	0	0	0
1973	-	4	0.6	0	0	0	0	0	0	0
1974	-	1	2.2	0.2	0.1	0	0	0	0	0.2
1975	78	15	3.7	0	0.1	0	0.5	0	0	0
1976	100	127	80.7	1.8	6.6	2.6	1.9	0	+	0.4
1977	6	-	6.2	0.8	0.8	0	0.2	0	+	0
1978	5	-	6.2	3.8	2.9	0.3	0	0	0	0.2
1979	5	-	0	93.2	61.3	14.3	6.5	0.5	0.3	0.5
1980	37	9	0	0	26.5	6.1	10.3	4.4	0.5	0
1981	22	216	-	0	2.1	67.6	39.4	20.2	9.5	4.3
1982	56	83	-	-	0	9.0	25.6	56.8	45.2	15.2
1983	83	226	-	-	-	-	16.6	18.0	44.4	74.2
1984	64	8	-	-	-	-	-	-	0	4.8
1985	75	8	-	-	-	-	-	-	-	0.2
1986	14	3	-	-	-	-	-	-	-	-

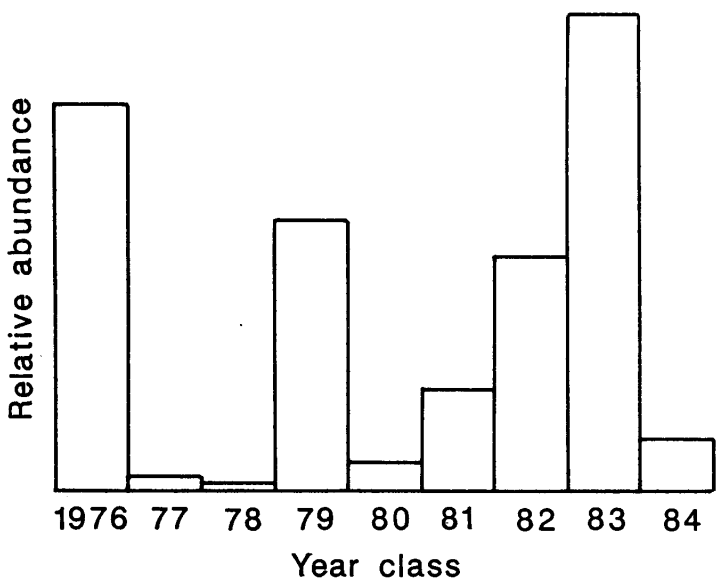

Figure 8 The relative abundance of bass in the successive year classes 1976-84 in the Solent, obtained by trawl surveys of 2-5-year-old fish.

4.3 The state of the stock

The national catches of bass, in numbers at each age for the years 1983-85, are shown in Figure 9. These are based upon increasingly comprehensive catch data obtained by regional MAFF and SFC staff and through the Fisheries Laboratory log-book scheme. Estimates of the quantities of bass landed in each ICES Area have been raised to numbers at age by using age-length keys obtained from the analysis of samples of the catches taken during these years. Figure 10 shows the extent of this sampling in 1985/86. The estimated numbers of fish in annual landings increased during 1983-84, but this was in part a consequence of the continuing improvement of catch

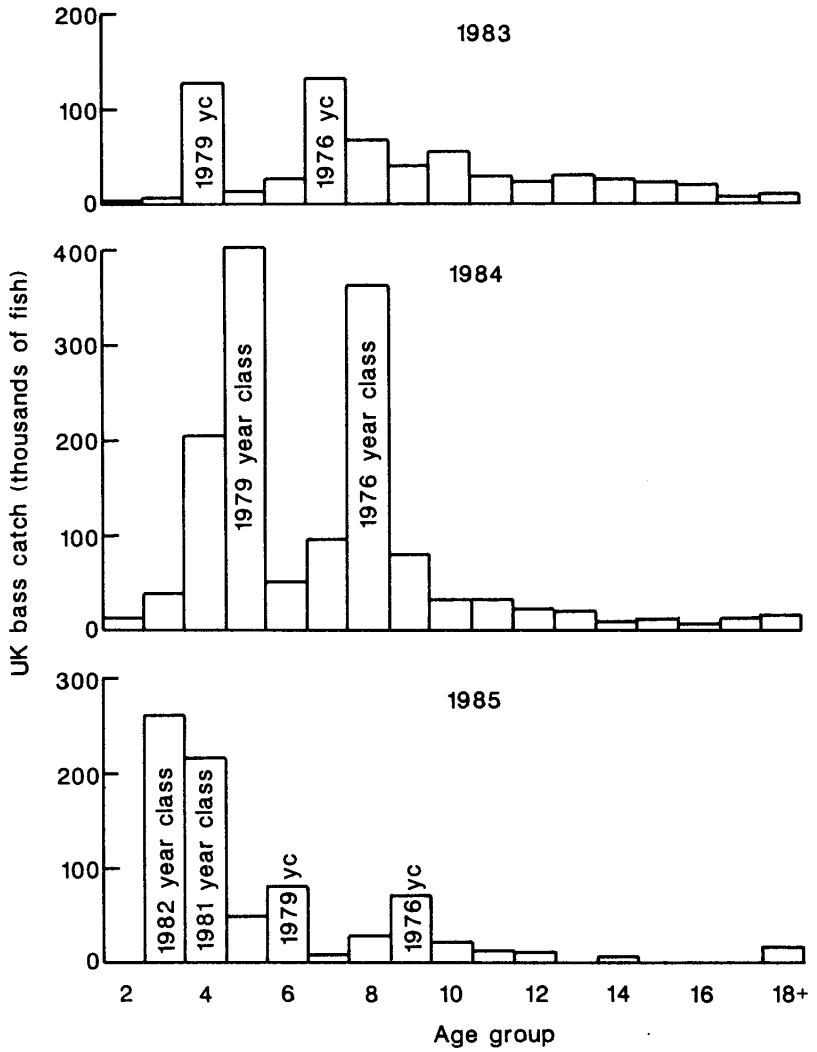

Figure 9 The age structure of the UK bass catch in each of the years 1983, 1984 and 1985.

and biological statistics for the bass fishery. Overall, landings in 1985 were down, due largely to adverse weather in the first half of the fishing season, although catch rates of fish in the age-groups 3-6 (taken mainly inshore) were maintained at the 1984 level. It is apparent that these small fish are the main target of a large part of the fishery for bass.

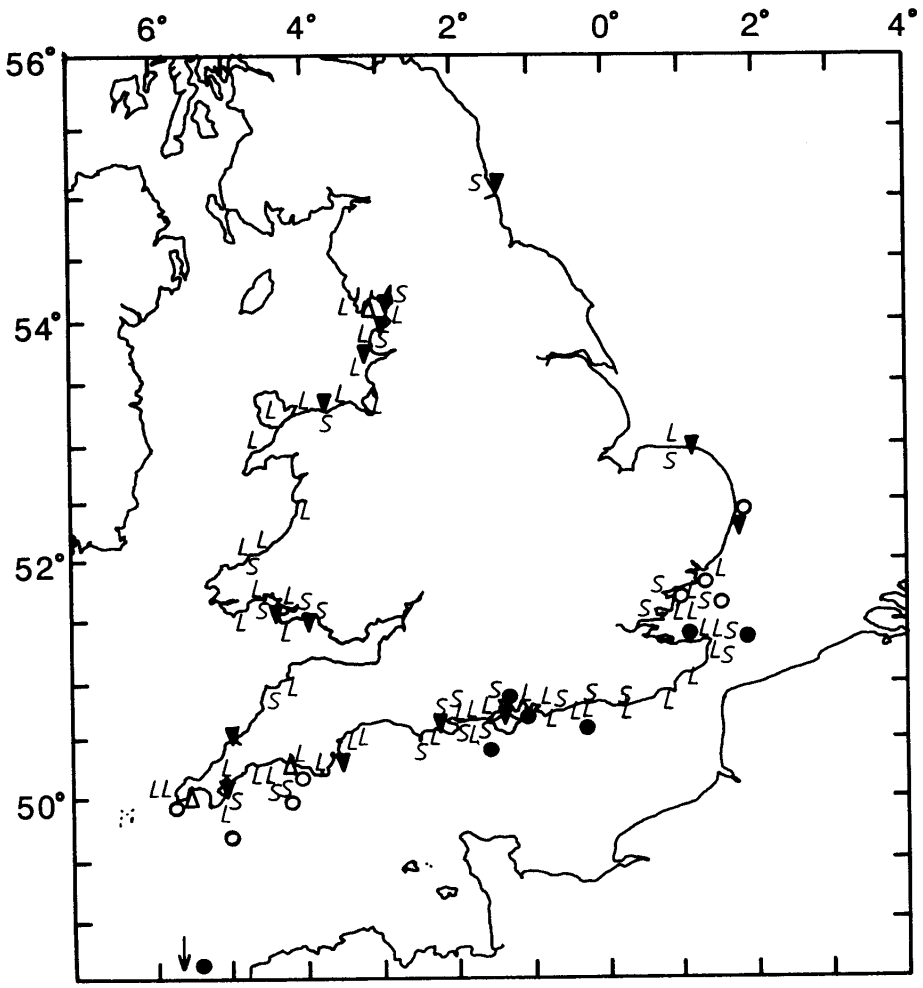

Figure 10 The sites at which the data used in the assessment of the bass fishery in 1985/86 were obtained: (Δ) official MAFF catch-weight statistics; (L) log-books of fishermen's catches in numbers and weight; (▼) other catch data; (o) MAFF port samples of length and age distributions; (●) research and survey samples of length and age distributions; (S) other length and age information.

The proportion of bass in the catch in 1983 which were 9 years and older (~ 40%) was higher than that estimated for 1984 and 1985 (~ 18%), chiefly, it is thought, because in the warm summer of 1983 more of these older fish were accessible to the fishery. The predominance of the 1979 and succeeding strong year classes in landings during 1984 and 1985 also resulted in the fishing pattern being redirected towards the younger age groups. An examination of log-book data, available for the same fishermen over the last 3-5 years, shows that there have been fluctuations in the annual catches of adult bass taken by a standard level of fishing effort. In some fisheries (e.g. west Cornwall) catch rates have declined and in others (e.g. south-west Wales) they have increased. We cannot be positive, therefore, that there has been any overall change in the abundance of adult bass during the study period, though it is likely that stocks have declined in the past as fishing pressure on them has been increased.

4.4 Regional exploitation patterns

Figure 11 shows the age distributions of bass caught in the various regions of the English and Welsh fisheries averaged over the years 1983, 1984 and 1985. The age structure in the catch is characteristic for each region, with fish recruiting to the fishery between ages 3-7 and showing a more or less rapid decline in numbers thereafter. In any one year, this pattern is distorted by the differences in relative abundance of each year class. Since 1981 the 1976 year class has predominated throughout the fishery, whilst the 1977 and 1978 fish have been relatively scarce, particularly east of Devon. The 1979 year class contributed strongly to catches in the central English Channel in 1983 and 1984, although it did not recruit significantly to the commercial fishery outside this region until 1985.

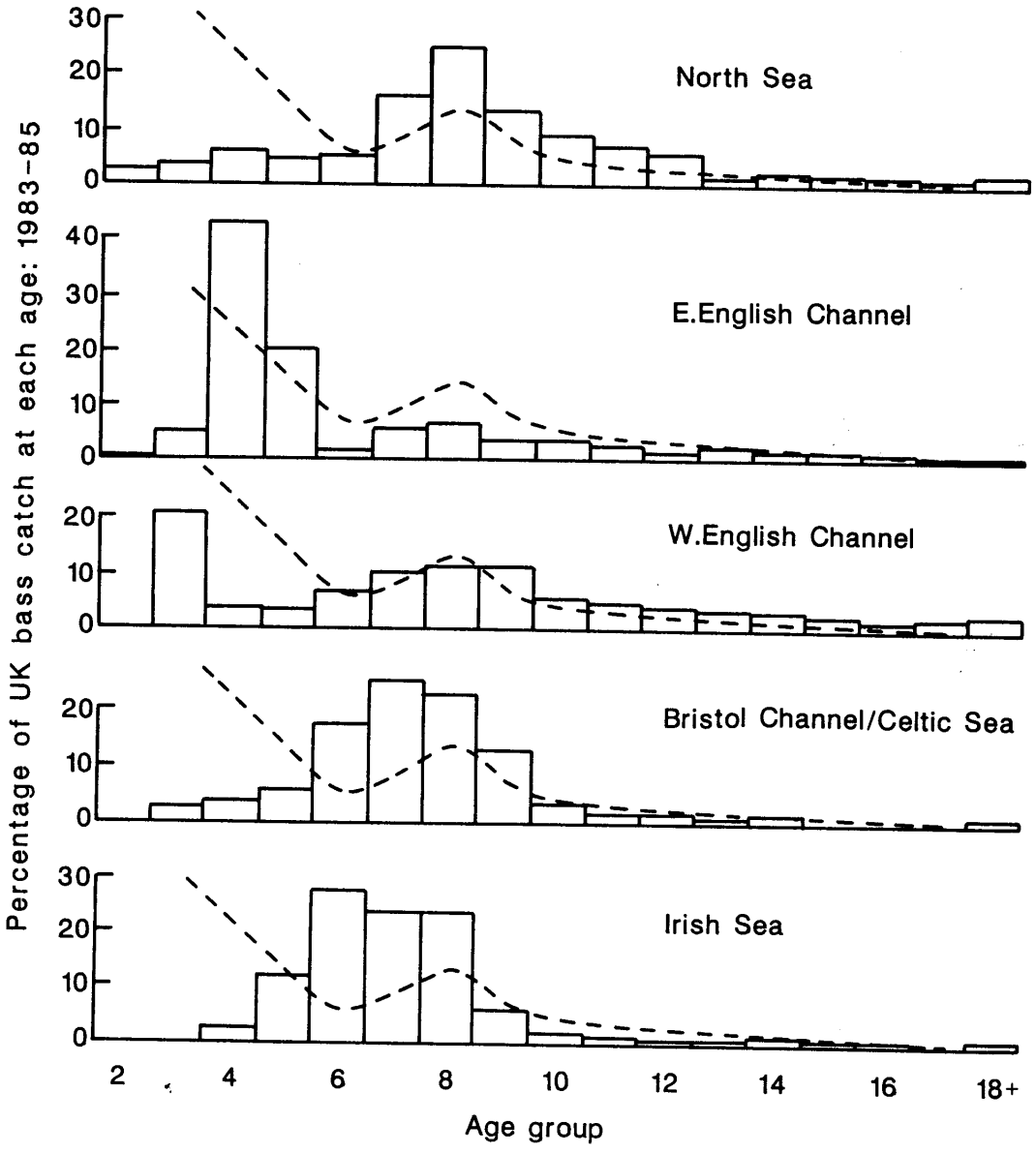

Figure 11 The age structure of bass in catches taken in 5 regions of England and Wales during 1983-85. The dashed line represents the age structure of the total national catch.

4.4.1 The Thames Estuary and southern North Sea

The fishery appears to be directed at bass mainly within the 7-11 age range, probably because of the fishing methods used. Of recent strong year classes, only the 1976 brood featured in landings until 1986, when the 1979 year class made an appearance. The age structure of catches taken in the offshore and inshore sections of the estuary and at different times of the year are similar, though the very large bass tend to be taken in catches from sand banks and wrecks situated well offshore.

4.4.2 The eastern English Channel

Small bass of 4 and 5 years old have been the mainstay of the fishery, but adults have recently become more important as fish of the abundant 1976 year class have grown, and appropriate effort has been directed at them. At times when there is a preponderance of juvenile bass in the Solent they attract much of the fishing effort and the pattern of exploitation is therefore influenced by the strength of recruiting year classes.

4.4.3 The western English Channel

This fishery exploits the full available age range of bass and appears to be least affected by year-class strength fluctuations. There is, however, a clear distinction between the fishery in the estuaries for juvenile bass (mainly 3- and 4-year-old fish) and that around reefs and offshore for the adults.

4.4.4 The Bristol Channel and Celtic Sea

Six- to nine-year-old bass predominate in catches, partly due to gill nets being used with mesh sizes too large to catch younger fish (100 mm MMS in south Wales), and partly because the fishery takes place close inshore where there is a reduced chance of taking older bass during most of the year.

4.4.5 The Irish Sea

The commercial fishery from west Wales to Cumbria is mainly restricted to 5-8-year-old bass at present because of gill net MMS regulations, though there appears to have been a relative scarcity of older fish. This feature is difficult to explain in view of the substantial adult population indicated by catches taken by lines and gill nets in south Wales in recent years. A likely cause is that large bass less frequently move as far north as formerly (the very abundant 1959 year class was predominant for many years), though there are indications that this trend has been reversed as the 1976 and subsequent strong year classes continue to grow.

5. TOWARDS A STRATEGY FOR MANAGEMENT OF THE BASS FISHERY

In order to decide how best to conserve an exploited fish population and to understand the effect that the introduction of control measures will have on the fishery, a knowledge of the ways in which the population is affected by fishing activity is required. Most of the data presented previously in this leaflet were collected with this aim in mind, and Sections 5

and 6 explain how they have been used to investigate the problems facing the bass fishery and to indicate how a practical solution may be found. We have tried to simplify the somewhat technical approach which fisheries science requires at this stage, but readers who would prefer to go straight to a discussion of the management strategy for the bass fishery and the means of its implementation are recommended to move on to Sub-section 5.4 on page 31.

5.1 The dynamics of exploitation

The numbers at each age in the total UK bass landings averaged over the years 1983/85, extrapolated back to 2-year-old fish (dashed lines in Figure 11), are assumed to represent the age distribution within the stock at that time. The exploitation pattern of the fishery in each region is given by the ratios of the proportion at each age in the catch there to that in the stock as a whole. These ratios have been used to model the changes in yield to the fishery (catch) which would be expected with changes in the age at which the bass are first caught, in order to illustrate the effects which different fishing patterns have on yields at a constant level of fishing effort (Figure 12, curves A-D).

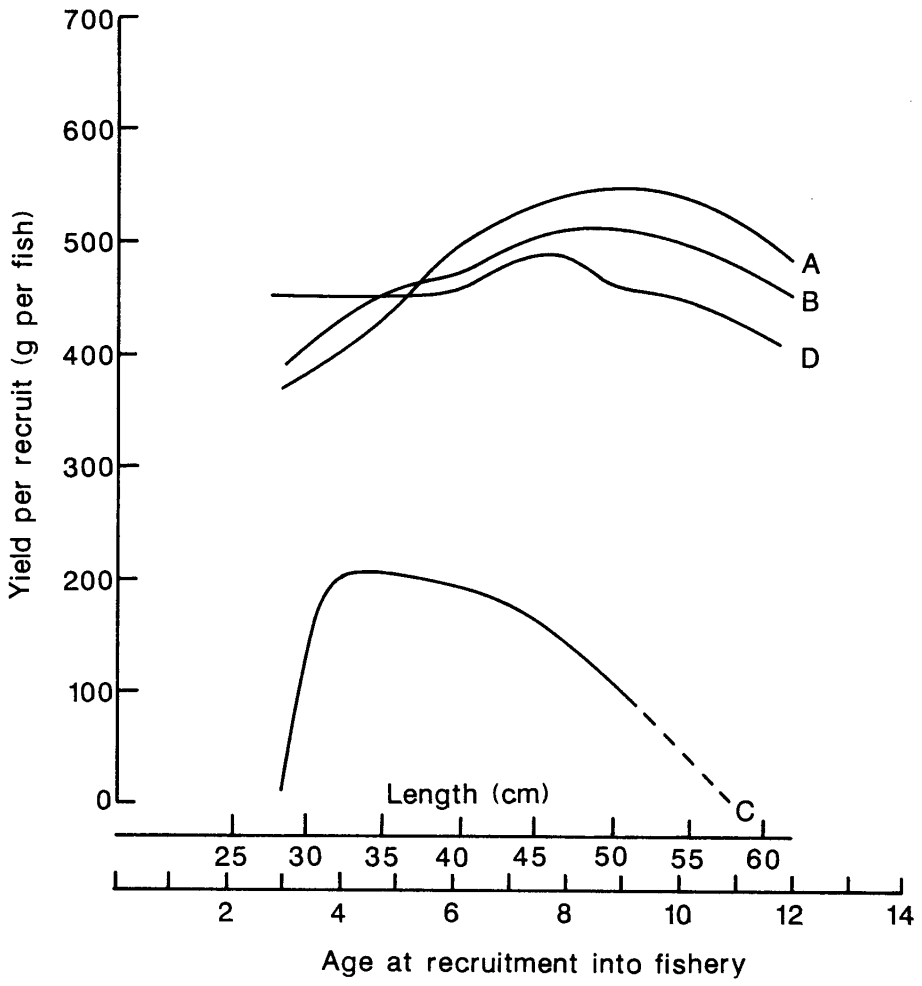

Figure 12 The effect of increasing the age at which bass are first caught on the yield to fisheries with the exploitation patterns of: (A) the total UK fishery; (B) the Devon and Cornwall fishery; (C) the west coast fishery; (D) the Thames Estuary fishery. All with Z = 0.25 and F = 0.15.

There are four important assumptions which require examination in order to judge the confidence which can be placed in the results. These are:

(a) The overall fishing mortality level on the stock affects each part of the fishery equally. This is likely to be valid for fisheries throughout the English Channel and southern North Sea; total annual mortality (Z) values indicated for fish aged 7 and over are similar at 0.25, and the central and eastern English Channel populations appear to mix freely. The population on the west coast until recently has been exploited in the Cornish winter fishery, where the age structure of adult bass in catches suggests that mortality rates are no higher than elsewhere. Similarly, large bass have been well represented in the developing south Wales fishery. It is possible, therefore, that the low adult numbers in catches further north on the west coast are not necessarily the result of higher exploitation rates, but are rather the result of poor recruitment to local adult stocks and a fishery which is directed at 5-8-year-old fish.

(b) Mortality due to causes other than fishing is constant, regionally and with age. Even with good fishing effort data, it is difficult to quantify 'natural' mortality (M) other than to use it to explain the difference between the calculated total mortality and losses due to the fishery (landings). For the bass fishery the assumption is that M = 0.1 per year, that is, 10% of the population dies each year as a result of natural causes. This gives the observed longevity of the species in UK waters (20 years or more) and indicates a fishing mortality (F) of 0.15 per year for fish of 7 years and older.

(c) All year classes are equally represented in each part of the fishery. Although the bass population is not distributed evenly throughout the UK fishery, neither geographically, seasonally nor from year to year, the age/size distributions have been similar within regions during the years 1983-85. This is taken into account in the calculations by the use of appropriate exploitation patterns. Apart from environmental influences (which contribute to fluctuations in year-class strength) and the effect of the fishery itself, the most likely cause of a change in the bass distribution is a very large year class spreading throughout the range of the population. This has occurred with the 1976 year class which has supported some previously insignificant fisheries (e.g. Morecambe Bay) and may also have happened with the 1959 year class, which dominated the west coast population until the early 1980s. It is possible that the adult stock from mid-Wales northwards is comprised mainly of such outstanding year classes.

(d) The strength of recruiting year classes has no effect on the exploitation pattern. Since 1981 the abundant 1976 year class has attracted considerable fishing effort, both through the use of appropriate gillnet mesh sizes (which generally increased from 1981 until 1983 as the fish grew) and in the choice of fishing method and location. During 1981 and 1982 only a small proportion of the landings in some fisheries (e.g. Solent, parts of the west coast) contained bass over 45 cm. In 1983 and 1984, however, the increased size of the 1976 fish demanded catching methods which will take larger bass (e.g. gill nets with meshes of 100 mm or larger and long-lines) and much greater numbers of 9-16-year-old fish were caught. This trend has already been seen to reverse in some fisheries in 1985 now that the good year classes of 1979, 1981 and 1982 have recruited. The use of catch-at-age data averaged over 1983-85 minimises this effect in the calculations.

The observation that fishing patterns change according to the relative abundance of recruiting age groups suggests that effort on bass would not diminish if the mean age of recruitment were raised by technical measures. In this event the yield should increase, provided that the part of the population still available to the fishery is no more difficult to catch than that part which is then protected. This may not be the case in the Solent, where there appears to be a peak of catchability in the size range 32-40 cm, which probably also applies to some local fisheries in other regions.

5.2 The conservation requirement

The results of MAFF surveys during 1982-85 indicate that the UK bass fishery has expanded considerably, both in the effort directed at bass and in the diversity of fishing techniques used. This has increased the mortality in the younger age-groups, especially the more abundant 1976, 1979, 1981 and 1982 year classes for which gill net mesh sizes have been adjusted as the fish have grown. But, although the variations in stock due to natural fluctuations in breeding success tend to mask the effects of increasing fishing pressure, there has been no indication of an overall national decline in the adult stock throughout the survey period. The spawning stock has shown itself to be still capable of producing strong year classes (see Sub-sections 4.1, 4.2 and Figure 8), and because mature fish are often less inaccessible to the fishery than are juveniles, there is little risk of a collapse of the bass population through inadequate spawning, provided that sufficient maturing fish are able to enter the adult stock. There is, therefore, no need for a restriction on the level of exploitation, and in view of the fragmentary and opportunistic nature of the bass fishery, neither catch quotas nor quantitative effort limitation are appropriate or necessary control measures.

Of more immediate concern, however, is growth overfishing, where the mortality of young fish is too high to enable sufficient fish to continue to grow and produce a high yield to the fishery. The distribution of adult bass, which makes them less catchable as they grow older and thus helps to preserve the spawning stock, also has the effect of concentrating fishing activity onto the younger age groups. If the present level of effort were directed more towards older bass (as it was in 1983), more juvenile fish would survive to become adults and a substantial increase in yield could be achieved, at the same time safeguarding spawning stock levels.

5.3 The effects of recruitment size on the fishery

Figure 12 (curve A) shows that a maximum yield for the UK bass fishery as a whole might be obtained if bass were first caught at an average length of 50 cm, provided that the fishing effort could be aimed towards larger bass as indicated above. The yield curve for Devon and Cornwall (Figure 12, curve B) approximates to this ideal because the fishery in this region has the capability to exploit bass of all ages, from juveniles in the estuaries to adults well offshore. In contrast, on most of the west coast (Figure 12, curve C) maximum yields would only be obtained with recruitment to the fishery at between 32 and 36 cm and a higher value would not enable yields to be maintained with the present fishing pattern. In the Thames Estuary bass under 40 cm are not so predominant in catches as elsewhere, and as the fishing pattern there is matched to the size structure of available bass, raising the recruitment size would achieve only a relatively small increase in yield. A maximum yield would be achieved at a recruitment size of

approximately 46 cm (Figure 12, curve D). The inshore fishery in the central English Channel is less easy to model, in view of the observed variability in exploitation pattern, which is influenced by the strength of recruiting year classes, but this flexibility in the fishing effort would probably enable it to adapt to changes in the size at recruitment up to at least 40 cm, in order to maintain yields.

Whilst it is necessary to protect the more vulnerable small fish and allow them to grow, this must be balanced by the need in all regions for the fishery to exploit bass of a size which would enable a high yield to be taken by the majority of those participating in the fishery at present. Too high a recruitment size would deny fishing opportunities for bass to those who have to rely solely on inshore waters for their livelihood.

The predictions of the effects of changes in recruitment size on potential yields in the UK bass fishery are based on the assumption that fishing patterns in the various regions are well established, having evolved to take maximal advantage of local resources (including species other than bass). If local effort were not modified to take account of an enforced change in the recruitment size for bass, then the benefits might not be obtained in the same fishery. There is also the prospect of a decrease in effort on bass in some regions if the size at recruitment were raised by technical measures. The magnitude of this potential (though short-term) loss in each region is illustrated in Figure 13, which shows the proportional catch in weight which would occur in each region with the present fishing pattern and various recruitment sizes. There would be a progressive decrease in catches on the west coast if bass recruited above 32 cm, but elsewhere, apart from the Solent, there would be less than a 10% loss even with a recruitment size of 44 cm. At this level, the UK fishery as a whole would probably suffer an immediate decrease in catches, of around 10%. We are confident, however, that there would soon be changes in the fishing pattern which would largely compensate for this loss, although the scale of the longer-term gain would depend on the degree to which the fishery could be restructured towards catching and marketing the larger bass. A maximum benefit of 25% is quite possible.

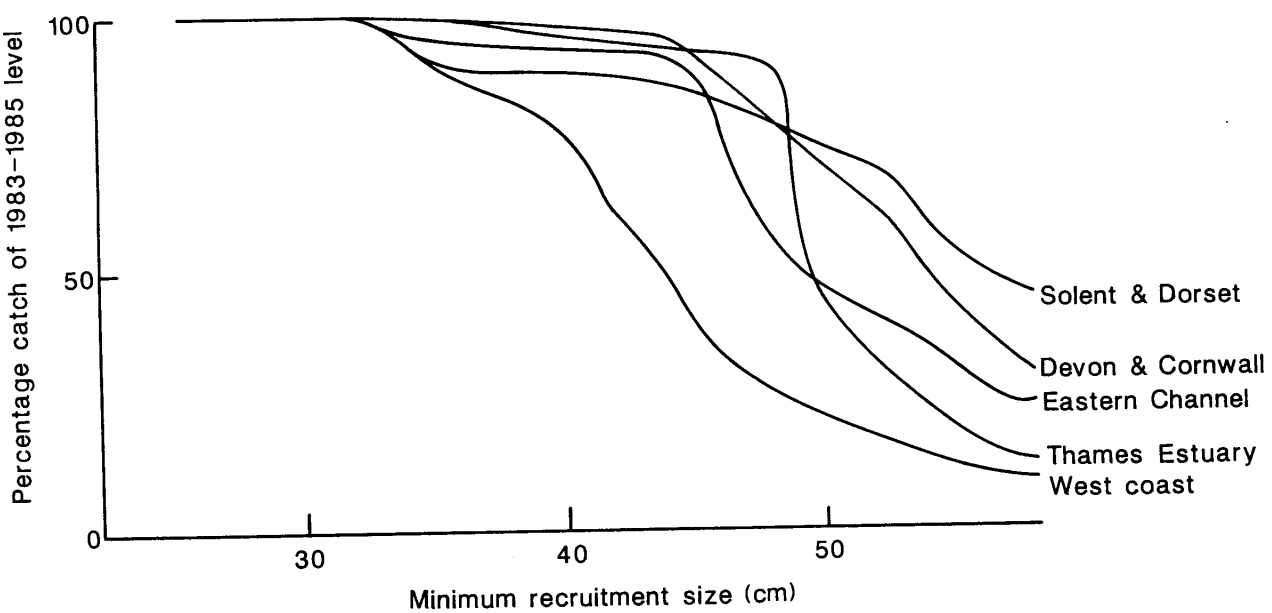

Figure 13 The expected short-term losses to the bass catch in 5 regions of England and Wales in relation to the size at which fish are first caught in the fishery.

5.4 The strategy

In summary, it appears that the size at which bass are first caught in the fishery could be raised to around 45 cm in order to increase yields in such regions as the Thames Estuary, eastern English Channel and around Devon and Cornwall. It is probable that there would be no benefit to the commercial fisheries in the Solent and on the west coast, in attempting to achieve a minimum size at recruitment higher than approximately 36 cm. There is concern, however, over a decline in catches of adult bass on some parts of the west coast, and it appears necessary to direct the fishery in this region away from bass under 40 cm in order to improve recruitment to the adult stock. Bearing in mind the vulnerability to capture of bass below this size and the need to divert fishing effort away from juveniles in general, the management strategy should be to delay recruitment to the fishery until bass reach approximately 38 cm.

With the present level of fishing activity, however, it is unlikely that any reasonable modification to the exploitation pattern would result in the number of adults in the stock approaching that which exists in an unfished population. Figure 14 compares the abundance of bass in each age-group which would be expected from a constant recruitment (using an index of one thousand 0-group entrants each year) under three different exploitation patterns. The number of recruits entering the adult stock would be similar whether the fish were first caught at age 5 in a redirected fishery, or maximally exploited between the ages of 4 and 8 inclusive, as in many areas at present. In the latter case, there would in fact be a lower mortality of adults and, theoretically, more large bass in the population, but only by forfeiting a potential doubling of the yield to the fishery.

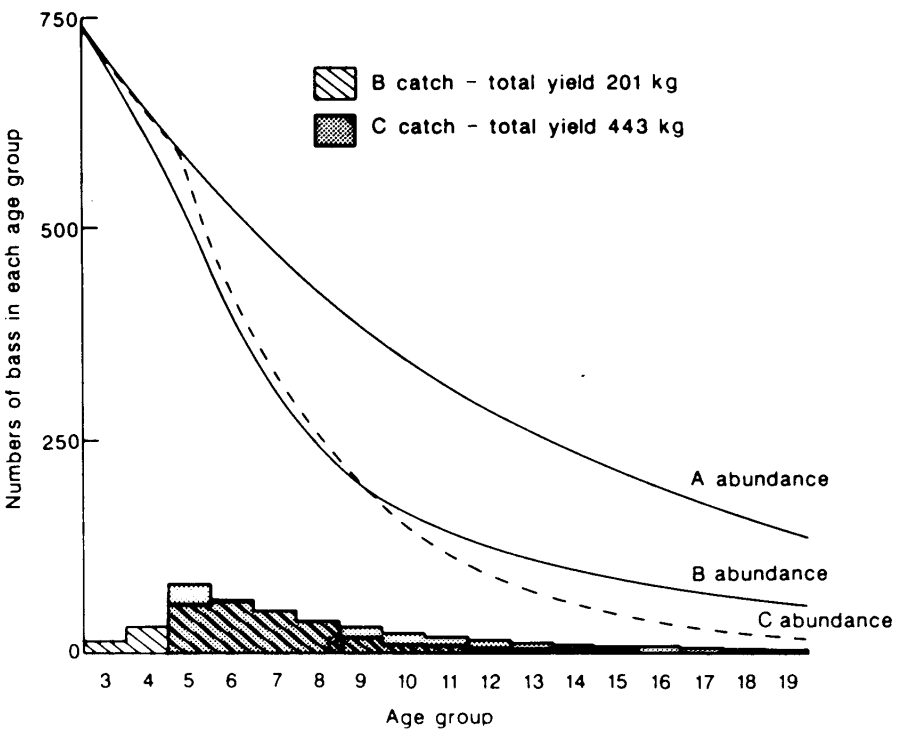

Figure 14 The effect of exploitation pattern at a constant level of fishing activity on the abundance and yield (catch in numbers at each age) to the fishery of a standard year class (starting as 1000 0-group) of bass as it goes through life: (A) no exploitation; (B) maximum exploitation at 4-8 years old; (C) constant exploitation from age 5 onwards.

6. MANAGEMENT TACTICS

6.1 Minimum landing size (MLS)

It is evident that an effective MLS of 38 cm total length would protect juvenile bass, increase the potential yield of the fishery and avoid growth overfishing. There are, however, regional differences which need to be taken into account in attempting management by MLS and it is acknowledged that, as the only legislation concerning bass, an MLS above the present value of 32 cm will not prevent a high mortality of juveniles, for three main reasons:

1. Undersized bass caught in drifting and set gill nets would suffer a substantial level of mortality even if discarded.

2. Bass of 3-5 years of age (approximate mean lengths 25-35 cm) are very vulnerable to angling in estuary mouths and other venues where they congregate, and it is thought that the quantities caught by even casual anglers constitute a considerable mortality (probably hundreds of thousands of fish each year) when viewed against the number of people participating.

3. There is a strong market demand for bass down to 24 cm.

Two further management tactics therefore are necessary to support an MLS in order to protect juvenile bass.

6.2 Gill-net mesh size limitation

Any MLS regulation requires complementary controls on mesh sizes, particularly in fisheries utilizing nets from which released fish have a low probability of survival. There is little justification, therefore, in allowing gill nets to be used with mesh sizes which would catch undersized bass, and which by their nature are also selective against the large fish towards which the fishery must be orientated. In view of the selection characteristics of gill nets and their adaptability to various fishing situations, it is not possible to specify a mesh size which would enable all bass under 38 cm to escape and still permit a high yield of larger fish. Our data show, nevertheless, that where an MMS of 89 mm is enforced less than 10% of bass retained by gill nets are under 35 cm. Retention curves for bass in various gill net fisheries in England and Wales, where mesh sizes ranging from 70 to 102 mm are used (Figure 15a, b), indicate that an MMS of 100 mm would be necessary to attain a recruitment size of 38 cm.

With the present fishing pattern, however, gill nets account for only 30-50% of the UK bass catch (see Table 1), and an MMS of 100 mm would thus afford protection to less than half of the juvenile bass population.

6.3 Closure of nursery areas

Although data on the catches and resulting mortality of bass under 32 cm are not available, it is acknowledged, by fishermen using small-meshed gear and by anglers themselves, that fishing activity in situations where bass of this size congregate can result in high levels of mortality. From an examination of the geographical and topographical distribution of the UK

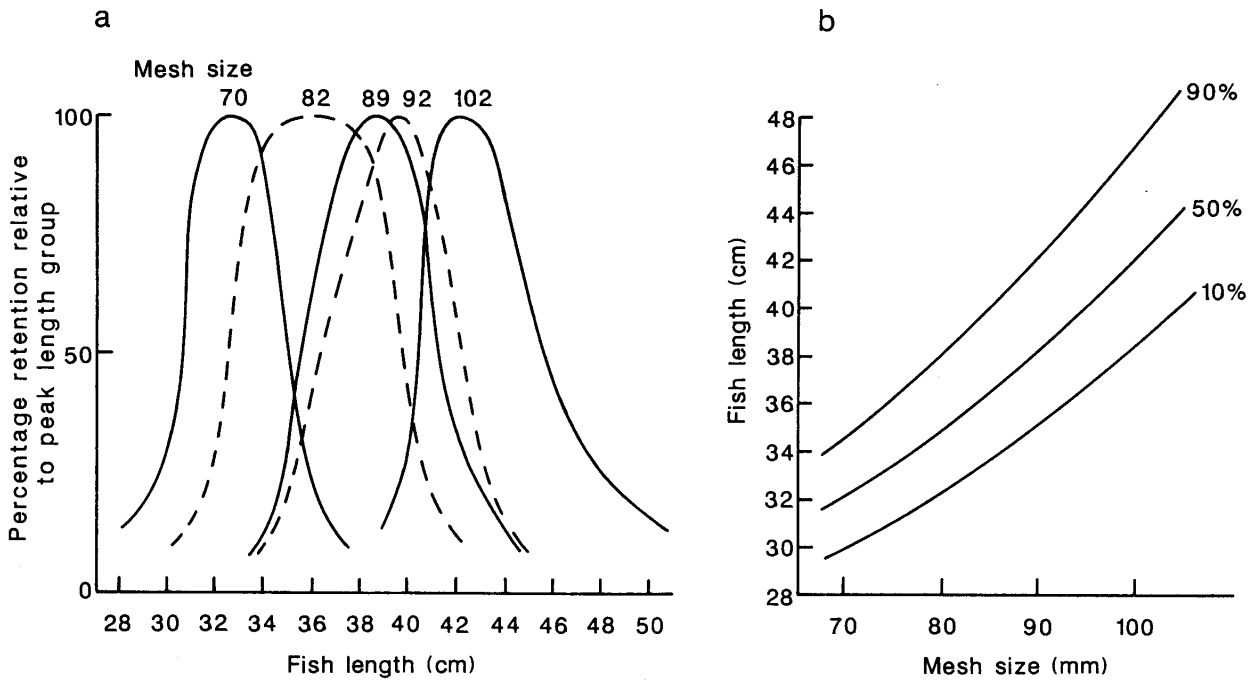

Figure 15 The relationship between the mesh size of monofilament gill nets and the size of bass caught in them: (a) retention curves for bass in gill nets with mesh sizes 70-102 mm stretched mesh; (b) the proportion of the bass catch which is below a particular size retained at various mesh sizes.

bass, it is possible to recognize distinct 'nursery areas' which contain a preponderance of juvenile bass. The prohibition of all fishing and angling activity in specified areas, where juvenile bass are known to be particularly vulnerable, would provide substantial protection against mortality other than that due to natural causes.

6.4 The preferred option

If it were possible to implement both an MMS of 100 mm for gill (and similar) nets and a closure of bass nursery areas to potentially harmful fishing activity, the resultant decrease in mortality of bass up to 5 years of age would provide protection comparable with an effective MLS of 38 cm. Given this degree of control over juvenile bass mortality a more modest MLS of 36 cm could stand, which would not only permit fishermen to land most of the smaller bass taken in gill nets with an MMS of 100 mm, but would also go some way towards satisfying the economic requirement to take bass under 40 cm in such fisheries as the Solent.

In many of the estuaries and harbours where areas could be closed to fishing to protect juvenile bass (and other species), fisheries exist which have little, if any, impact on bass stocks, and arrangements for exceptions to the prohibitions would be needed to allow these fisheries to continue.

Similarly, there are some locally important gill net fisheries for other species (mullet, sole, herring, sprat, mackerel, pilchard) in which mesh sizes below 100 mm could be permitted without compromising the aim of these recommendations for the bass fishery.

7. CONCLUSIONS

The results of our study support Holden and Williams' (1974) view, that raising the size at which bass are first caught in the commercial fishery to around 38 cm total length would protect the spawning stock and increase the potential yield to the English and Welsh fisheries. At present these fisheries rely heavily on bass in the size range 32-40 cm, which occur inshore throughout the year, and whilst there is a need to allow controlled exploitation of bass under 40 cm in length the fishing effort must be redirected towards the adult stock.

Except in the Eddystone bottom trawl and fly-seine fishery, the English fleet does not yet compete directly with French vessels for large bass (45 cm upwards) in the offshore winter fishery in the English Channel, but tagging has indicated that these fish contribute to the Thames Estuary fishery in the summer. There have, however, been no recoveries from foreign vessels of juvenile fish tagged on the south coast of England, and the management tactics presented above would not appear to put the UK fishery at a disadvantage.

On the west coast, protection for juveniles must be increased in order to maximise recruitment to the adult stock, which appears to have declined since the 1960s. A deterioration in the quality of sport angling for bass, particularly in the average size of fish caught, was apparent on some parts of the coast before the expansion of the commercial fishery. This may have been due to poor spawning success, but is more probably the result of increased exploitation of local populations by angling. The proposals for managing the bass fishery described above would benefit the large number of sea anglers as well as the commercial fishery with which they co-exist. However, both groups would be expected to modify their fishing patterns somewhat in order to accommodate the precautions necessary to promote the optimal use of the bass resource.

8. REFERENCES

DANDO, P. R. and DEMIR, N., 1985. On the spawning and nursery grounds of bass, Dicentrarchus labrax, in the Plymouth area. J. mar. biol. Ass. U.K., 65: 159-168.

HOLDEN, M. J. and WILLIAMS, T., 1974. The biology, movements and population dynamics of bass, Dicentrarchus labrax, in English waters. J. mar. biol. Ass. U.K.: 54: 91-107.

KELLEY, D. F., 1979. Bass populations and movements on the west coast of the UK. J. mar. biol. Ass. U.K., 59: 889-936.

KELLEY, D. F., 1986. Bass nurseries on the west cost of the UK. J. mar. biol. Ass. U.K., 66: 439-464.

KENNEDY, M. and FITZMAURICE, P., 1972. The biology of the bass, Dicentrarchus labrax, in Irish waters. J. mar. biol. Ass. U.K., 52: 557-597.

PAWSON, M. G., KELLEY, D. F. and PICKETT, D. G., 1987. The distribution and migrations of bass, Dicentrarchus labrax L., in waters around England and Wales as shown by tagging. J. mar. biol. Ass. U.K., 67: 183-217.

THOMPSON, B. M. and HARROP, R. T., 1987. The distribution and abundance of bass (Dicentrarchus labrax L. 1758) eggs and larvae in the English Channel and southern North Sea. J. mar. biol. Ass. U.K., 67: 263-274.

Appendix 1 Glossary of technical terms used in the text

Adult/juvenile: The distinction between the adult and juvenile parts of a fish stock is usually expressed as the size or age at which half the stock reaches maturity.

Age group: Those members of a fish stock which have the same age in years. The birthday of marine species in northern temperate waters is conventionally taken as 1 January; thus fish in their first calendar year are 0-group; those in their fifth, 4-group.

Exploitation pattern: The relative proportion of each age group in a stock which is caught in a fishery. Essentially the interaction between fishing pattern, stock distribution and fishing mortality.

Fishery: The combined activities of a fishing fleet and its use of catching gear to supply a processing infrastructure and market by exploiting a fish population. Usually described by reference to a single species, geographic region and/or catching method.

Fishing pattern: The characteristic combination of the seasonal and geographic use of various methods in a fishery.

Maturity: The attainment of gonads which contain ripe eggs or milt and are thus ready for spawning. In most marine fish species the spread of ages/sizes at which maturity is reached is much greater than any differences between the sexes.

Mesh selection: The property of a net to retain or allow the escape of fish of one species within a given size range; the selection pattern being the proportion at each size (or age) encountering the net which is caught.

Migration: The regular, purposeful movements of a stock of fish which, though extensive, do not result in its overall distribution changing from year to year.

Minimum landing size (MLS): The size (usually total length in cm) below which a specific marine fish may not be legally landed from a fishing vessel or offered for sale.

Minimum mesh size (MMS): The size of mesh - measured lengthwise between opposing knots when the mesh is stretched diagonally - below which it is illegal to use specified fishing nets (of a type or for fish species).

Mortality: The (numerical) proportion of a fish stock which dies each year; comprising the catch taken by a fishery (fishing mortality) and deaths due to other causes (natural mortality).

Nursery area: The environment occupied by the majority of juveniles in a fish stock. This can often be described in geographical terms.

Population: A group of individuals (of one or several species) living within a designated geographic areas or environment.

Recruitment: The entrance of growing fish to a fishery, (a) as they become large enough to be caught by the catching gear and/or (b) as they move into the fishing area or undergo a behavioural change which allows them to be caught.

Sea Fisheries Committee (SFC): The local regulatory authority which is responsible for management of marine fisheries within the zone 3 nautical miles to the seaward of low water mark.

Stock: That part of the total population of a single (fish) species which is self-maintained and (usually) exploited by a distinct fishery or subject to a particular management regime.

Tag: An individually coded device, usually of plastic or metal, which is attached to, or inserted into, the body of a fish for the purposes of identification upon recapture.

Year class: Those members of a fish stock which were hatched in the same calendar year.

Year-class strength: The numerical abundance of a year class; usually expressed in relative terms by comparison with preceding and succeeding year classes.

Yield: The catch in weight which a given fishery takes from a stock during the course of each year.

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