Seasonal Migrations of the Common Goby, Pomatoschistus microps (Kroyer), in Morecambe Bay and elsewhere

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(with 5 figs.)

INTRODUCTION

The Common Goby, *Pomatoschistus microps* (KRØYER), is a euryhaline marine gobiid (Teleostei-Percomorphi) which ranges through the Mediterranean and along the Atlantic coast of continental Europe to Trondheim, Norway, and into the Baltic (DUNCKER, 1928). The species has been reported from estuaries, saltmarsh, and intertidal pools around the British Isles from Plymouth to Orkney (MILLER, 1963). In the Isle of Man, where the biology of this species has recently been investigated by one of us (MILLER, 1963, 1965), *P. microps* reaches a maximum total length of 64 mm and has a short lifespan, few individuals surviving their second winter of life. Sexual maturity is reached in the spring or summer after the first winter of life, and the long breeding season lasts from April to the end of August or the beginning of September. During this period, individual females may produce several batches of eggs.

The present paper deals initially with long-term observations by one of us (DJ) on *P. microps* at Morecambe, Lancashire. These

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results are compared with existing information about seasonal movements of this goby in other parts of the British Isles and northern Europe, and a relationship suggested between occurrence of migration and winter sea-temperatures (PJM). The fish-fauna of Morecambe Bay has been listed in some detail by HERDMAN & DAWSON (1902), FRASER (1935), and ELLISON & CHUBB (1962). Both hydrography and physiography of this area are described in the first two of these publications. Five species of gobiid fishes have been recorded from Morecambe Bay. In sublittoral waters, *Pomatoschistus pictus* (MALM) is common on gravel deposits where commercial prawning is undertaken (FRASER, 1935), *P. minutus* (PALLAS) occurs in sandy shallows (personal observation), and the pelagic *Aphia minuta* (RISSO) is known from the Barrow Channel (HERDMAN & DAWSON, 1902). Apart from *P. microps*, which is by far the most abundant intertidal goby along the entire eastern seaboard of the Irish Sea (MILLER, 1961; ELLISON & CHUBB, 1962), juvenile *Gobius paganellus* L. inhabit the shore pools of the Morecambe mussel beds in late summer and autumn, and, very rarely, examples of *P. pictus* may also occur there (personal observation).

AREA AND METHODS

The population of *P. microps* studied inhabits intertidal pools on extensive mussel beds ("scars", "skears") which cover a large area of the otherwise sandy shore between Heysham and Morecambe, and which in the present work are referred to as the Morecambe mussel beds. They represent an enormous concentration of the Edible Mussel (*Mytilus edulis* L.) which has been harvested by man since at least as long ago as the thirteenth century (SCOTT & BAXTER, 1906), and remain among the most important commercial beds on the west coast of England and Wales (SIMPSON, 1960). At low water of spring tides, the beds stretch in almost an unbroken line for over two miles from in front of Heysham Promenade to Grange Channel (Fig. 1). The substrate is coarse ground, mainly of small stones with scattered larger rocks. Silt accumulates after colonisation by the mussels and, between the low banks thus formed, intertidal pools are numerous (Plate I, Fig. 1). The exact limits of the beds are subject to variation under the influence of sand and water movements. In the upper intertidal zone, the beds appear more stony with mussels becoming scattered in distribution.

From 1956 to 1961 the intertidal area of Heysham Flat and Knott End Skear was examined at low water by one of us (DJ) on at least six occasions in every month. In searching the pools, stones and shells were removed but poisoning was not carried out. Lack of time and

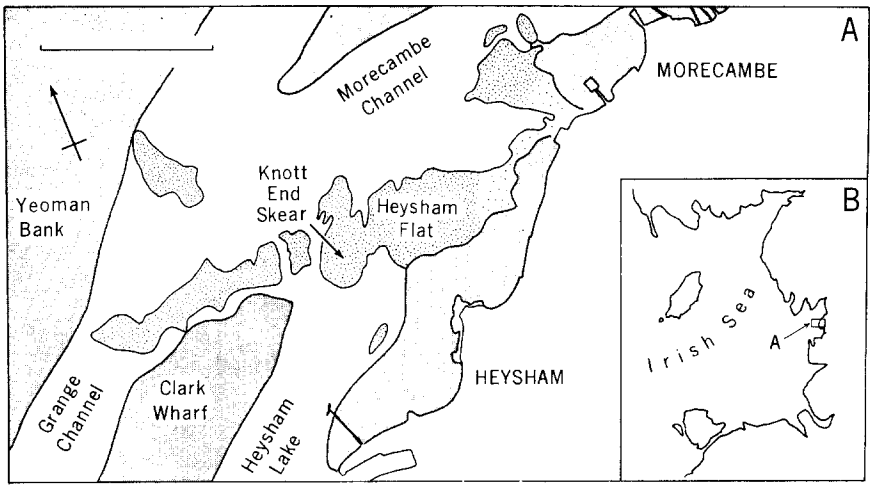

Fig. 1. Map of Morecambe and Heysham shore at LWST; coarse stipple, mussel beds; fine stipple, sand. Position of area (A) shown in (B); scale in (A) one mile. After SCOTT & BAXTER (1906).

laboratory facilities did not permit the collection and detailed study of large samples of the *P. microps* population. An arbitrary system of recording numbers of individuals was followed, the terms 'present', 'common', and 'abundant' being employed to denote recognised degrees of occurrence. While essentially subjective, this system of notation enables broad comparisons to be made between different months and years when practised by the same observer. The temperature of the sea at the edge of low water was recorded on several occasions throughout each month of the six years of work (Table I). These results have been compared (Fig. 2) with sea surface temperatures taken at the Morecambe Bay Light Vessel, situated in the eastern Irish Sea at 53° 55′ N, 3° 29′ W. The inshore temperatures are only

TABLE I.

Monthly mean sea temperature at low water on Heysham Flat and Knott End Skear, 1956 to 1961.

Month	Overall Mean °C	Range in means Min. °C	Range in means Max. °C	Month	Overall Mean °C	Range in means Min. °C	Range in means Max. °C
Jan.	3.00	2.11 (1959)	3.78 (1956)	July	16.17	14.72 (1961)	17.83 (1959)
Feb.	3.34	1.11 (1956)	5.94 (1961)	Aug.	15.26	12.94 (1956)	17.39 (1959)
Mar.	5.27	2.11 (1958)	6.94 (1959)	Sept.	13.81	11.28 (1957)	16.22 (1959)
Apr.	8.29	6.00 (1958)	9.89 (1960)	Oct.	10.17	9.00 (1960)	12.33 (1959)
May	12.57	10.28 (1957)	15.00 (1960)	Nov.	6.53	5.39 (1960)	8.56 (1958)
June	14.95	13.72 (1956)	16.44 (1960)	Dec.	4.26	3.17 (1960)	5.06 (1959)

higher than the latter in spring; from July, increasing disparity between their respective values culminates in the noticeable difference over late autumn and early winter, when inshore temperatures are markedly lower. In these features, the inshore sea temperatures resemble the prevailing air temperatures at Morecambe (Fig. 2) as might be expected in a relatively shallow bay with very wide intertidal flats.

Seasonal migration and reproduction

During the winter of most years, the population of *P. microps* occurring on the intertidal mussel beds was noted to be at best considerably smaller than in other seasons. Over the winter months of January and February in 1956 and 1959, in February 1958, and in January 1961, no examples of the species could be found on the mussel beds. At other times, small numbers occurred in these months but were usually restricted to upper shore pools. *P. microps* was more numerous than usual during January 1957, with some individuals occurring in lower pools. Sea-temperatures for this month were not abnormally high.

In spring, *P. microps* became progressively more numerous on the mussel beds, being common in March 1957 and 1960 and in the following month of other years, and already abundant in April of 1957, 1960 and 1961. With the spring increase in population, the pools on the lower beds were found to become frequented by appreciable numbers, which were particularly high in 1957, when gobies were common in May at the edge of the tide. Spawning took place usually from April to August, with the resulting newly metamorphosed young fishes appearing on the shore in June (July 1956 and 1959). These were especially common in the upper pools, but also present in lower pools and at the edge of the sea in 1959 and 1960. By July, they were abundant on the upper beds and, in 1959, remained so even at the edge of the sea. In general, recruitment of young fishes to the demersal population seemed highest in 1958 and 1959, and lowest in 1961. By the end of August, some of the young fishes had reached a size at which it was impossible to distinguish them by length-frequency distribution from the adult breeding population. The latter usually remained abundant in the upper pools throughout the summer. Recruitment of juveniles from the plankton continued until September, or October in 1956 and 1958 (Table II). In September, when the photographs in Plate I were taken, the upper pools contained an abundant mixed population of juveniles and adults, spawning by the latter having ended in the previous month. During

October, *P. microps* remained very numerous and was noticeably concentrated in groups in larger pools rather than inhabiting all the available upper pools of the beds. In November, while usually still abundant in upper pools, gobies were missing or scarce on the lower beds. At the onset of winter, the December intertidal population was usually greatly reduced, and in 1960 and 1961, *P. microps* appeared to be entirely absent from the shore. The sea during the preceding November in both years was unusually cold.

TABLE II.

Date of occurrence of earliest and latest nests and newly metamorphosed young, and months in which nests were abundant in mussel bed pools.

Year	Nests first found on:	Nests last found on:	Nests abundant in:	Metamorphosed young first found on:	Metamorphosed young last found on:
1956	5 May	22 Aug.	late May to late July	5 July	12 Oct.
1957	2 Apr.	22 Aug.	late April to early June	11 June	2 Sept.
1958	16 May	21 Aug.	late May to early June	5 July	21 Oct.
1959	5 May	13 Aug.	early May to early July	13 June	23 Sept.
1960	27 Apr.	22 July	late April to early June	22 June	23 Sept.
1961	25 Apr.	23 Aug.	late April to late May	14 June	23 Sept.

Like many other gobies, the males of *P. microps*, in nuptial dress, prepare nests, engage in elaborate courtship behaviour, and guard the fertilized eggs until hatching (GUITEL, 1892; NYMAN, 1953). At Morecambe, eggs were laid under dead shells or stones in pools, and the observed reproductive behaviour agreed exactly with published accounts. Nests were almost entirely confined to the upper beds, and only three in six years were found in lower shore pools. Table II shows the dates of finding of the first and last nests, and months of abundance of nests, for each year. Except for 1956, it seems likely that spawning usually commenced in April, being particularly early in 1957. Absence of records of nests for April 1958 and 1959 is probably related to generally smaller numbers of fishes on the shore in those years, and consequent reduction in the chances of finding nests, which were abundant in the following month in both years. Breeding activity appeared to be greatest usually during May and June. Nests became less common in July and August, and none were discovered after the latter month. In general, newly metamorphosed young fishes appeared for the first time in June and were not found after September, although, in both 1956 and 1958, they occurred from July to October (Table II). The duration of planktonic life has been roughly estimated from the interval between the first occurrence on the shore of large numbers of nests and young gobies respectively,

and appears to be from about six to nine weeks. Young fishes were noticeably most abundant on the shore in 1959, and least so in 1961, the warmest and coldest summers of the period of field work.

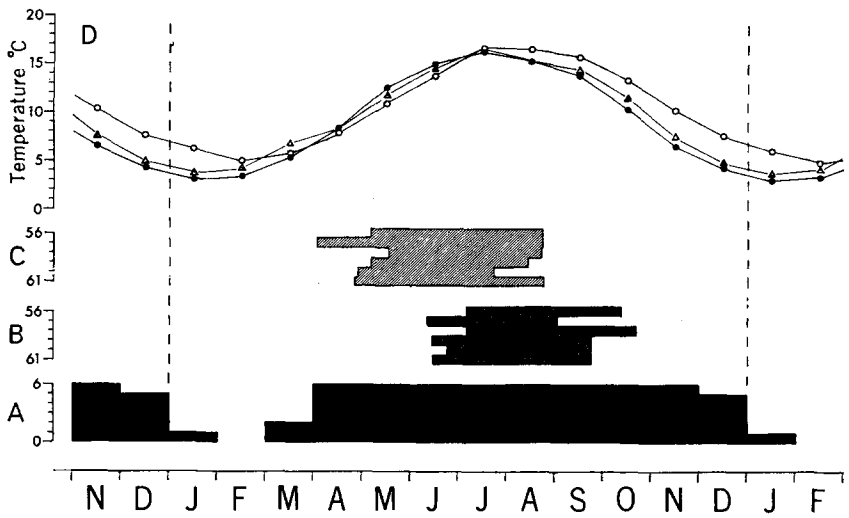

Fig. 2. Life-history of *P. microps* at Morecambe during 1956—1961, and annual temperature cycle. A, number of years in which *P. microps* was common or abundant for each month; B and C, limits of occurrence in pools of newly metamorphosed young and nests respectively for each year. D, mean monthly temperatures for 1956—1961; closed circles, sea at edge of LW on skears; open circles, sea-surface at Morecambe light-vessel; open triangles, air at Morecambe.

To summarise, the annual cycle in abundance (Fig. 2) of *P. microps* on the mussel-beds of Morecambe seems clearly explicable in terms of migration between intertidal pools and a sublittoral winter habitat. In the present work, collecting below LWS was not possible and the precise distribution of the species in sublittoral water in winter is unknown. During spring, there is an onshore migration of adult or maturing fishes which establish a breeding population situated predominantly in the upper pools. Young fishes hatched during the breeding season return to the shore on metamorphosis and, at least initially, show the same predilection for the pools of the upper beds. At the end of autumn, there is a disappearance of young fishes and surviving adults from the shore, and this may be interpreted as an offshore migration on the part of most of the shore population. These migrants return to the shore in the following spring, after the commencement of sexual maturation, or recovery of spent gonads, in the winter. There is a clear correlation between these movements and sea

temperature (Fig. 2). Thus, the shore pools are largely vacated in the earlier half of winter, when temperatures are falling from about 5°C to 3°C, and are repopulated in late winter and spring over a period of temperature increase from about 3°C to 7°C. Comparison between sea temperatures recorded at the Morecambe light-vessel and those at the edge of low-water suggests (Fig. 2) that winter migration from the shore would carry the population into water a few degrees warmer than that in the extreme shallows and pools.

Migration in other areas

In contrast to these events described for Morecambe (Fig. 3: 7), one of us (Miller, 1963) has found that *P. microps* is fairly numerous in winter in the upper reaches of the small Silver Burn estuary at Castletown, Isle of Man, and also in brackish shore pools at neighbouring localities (Derbyhaven, Poyllbrein) (Fig. 3: 1). The Manx area studied is slightly more than 70 miles due west across the Irish Sea from Morecambe but with the average sea surface temperature for February at least 2°C higher than in Morecambe Bay (Bowden, 1955). During spring, there is a downstream migration in the Silver Burn estuary, establishing a breeding population in the lower reaches and depleting the upper estuary of *P. microps*, but no evidence was obtained for movement of this species into the estuary after overwintering in the sea.

In the south-east corner of the Irish Sea, where the temperature regime is similar to that of Morecambe Bay, *P. microps* is rare or absent during winter in shore pools of the Wirral Peninsula in Liverpool Bay (Fig. 3: 8), but has been noted to be present in the much larger and deeper Marine Lake at West Kirby when this has been drained in winter (PJM, personal observation). Around Anglesey (Fig. 3: 9), *P. microps* was found to reappear in shore pools during April 1964, presumably following migration from a sublittoral winter habitat (R. Gibson, personal communication); annual minimum sea temperature (in February) at Menai Bridge is usually about 5°C (Crisp et al., 1964). On the Bristol Channel, Brough, Delhanty & Thompson (1964) record *P. microps* (as *Gobius minutus*) entering a pool in January 1961 at high tide on the Lamby saltmarsh, near Cardiff (Fig. 3: 4); although ice had formed on the pool prior to tidal inundation, the latter raised the temperature to about 6°C. This observation suggests that *P. microps* may remain inshore and intertidally over winter on the south Wales coast. Along the North Sea coast of the British Isles, average February sea-temperatures normally lie between 3°C to 5°C, and resemble those of the eastern Irish Sea. On the Essex coast (A. C. Wheeler, personal communication), *P.*

microps is very common in summer between tide-marks and at the edge of low water (Fig. 3: 10). In winter, the population becomes much reduced in these habitats, but from January to March examples are taken by trawling mostly at 3 to 6 fathoms in the upper Crouch estuary, being absent at these depths in summer. An unusually large number of *P. microps* was trawled on 19 February 1963, during the severe winter of 1962—63. Individuals remaining in the shallows or on the shore may be killed by sharp frosts in early winter.

Elsewhere over the range of distribution of this species, seasonal migrations have been reported for *P. microps* in the Baltic (NYMAN, 1953), Belt Seas (DUNCKER, 1960), and Skagerrak (COLLETT, 1875), with movement into deeper water in winter and a return to the shallows in the spring for breeding purposes (Fig. 3: 17, 14, 16 respectively. At the mouth of the Gulf of Finland (Fig. 3: 17), the fishes do not reappear until May (NYMAN, 1953), but may be found close inshore as early as March in the Kattegat (Fig. 3: 15) (WINTHER, quoted by SMITT, 1892). A similar winter migration appears to occur in the southeast corner (Fig. 3: 13) of the North Sea (DUNCKER, 1960). Recent work on annual cycles in the occurrence of demersal fishes in the Dutch Waddensea (Netherlands Institute for Sea Research, 1963; M. FONDS, personal communication) has provided clear evidence of seasonal migrations by both *P. microps* and the related species, *P. minutus* (see below). In the case of the former, which is normally abundant during summer in intertidal habitats of the area (Fig. 3: 12), results (Table III) from regular trawling in the Waddensea (October

TABLE III

Number of P. microps taken by beam-trawl (beam 3 m., fine meshed bag) in Dutch Waddensea, October 1961-September 1962, at two depth ranges. Sea surface temperatures recorded from the enclosing dam Breezanddijk bounding the IJssel Meer. All data provided by Mr M. Fonds.

Date	Shallow water (2.1-5.3 m)			Deep water (5.3-11.3 m)			Monthly mean sea surface temperature	
	Total time fished (mins)	No. of P. microps	No. of P. microps per 20 mins	Total time fished (mins)	No. of P. microps	No. of P. microps per 20 mins	Month	°C
23 Oct.-1 Nov. '61	45	18	8	35	2	1	Oct. '61 Nov.	13.65 6.40
11 - 15 Dec.	48	30	13	31	32	21	Dec.	3.35
9 - 11 Jan. '62	20	-	-	96	92	19	Jan. '62	2.65
6 - 9 Feb.	30	6	4	100	10	2	Feb.	ice
28 Mar.-4 Apr.	30	95	63	140	15	2	Mar.	1.70
24 - 26 Apr.	30	8	5	120	-	-	Apr. May	7.20 10.35
5 - 7 June	30	-	-	120	-	-	June	14.75
17 - 20 July	40	-	-	70	-	-	July	15.00
13 - 16 Aug.	40	14	7	110	-	-	Aug.	15.95
25 - 28 Sept.	25	7	6	85	15	4	Sept.	14.15

1961-September 1962) suggest a migration from the shore to relatively shallow water in autumn, and further movement into deeper parts in winter. By the beginning of spring, an inshore migration has taken place, with the population becoming largely intertidal by the end of April. In the upper estuary of the Scheldt (Bas Escaut) below Antwerp (Fig. 3: 3, 11), LELOUP & KONIETZKO (1956) noted a partial migration of this species from ditches and pools on autumn high tides, but stated that the species was widespread in the area throughout the year and recolonised these habitats in the spring.

DISCUSSION

The occurrence and nature of seasonal migration in *P. microps* thus varies over the geographical range of the species. Comparable differences in behaviour with locality have been described by SWEDMARK (1958) for the related sublittoral *P. minutus*. In the Gullmarsfjord, Swedish Skagarrak (Fig. 3: 18), there is a movement of individuals into slightly deeper water in late autumn with return of ripe fishes to the shallows in the ensuing spring. It has also been noted recently that the Dutch Waddensea (Fig. 3: 19) is vacated by *P. minutus* in winter (Netherlands Institute for Sea Research, 1963) and the same species is much less common during winter in the Crouch estuary, Essex (Fig. 3: 20) (A. C. WHEELER, personal communication). However, seasonal migration of this kind is not shown by populations of *P. minutus* investigated on the coast of Brittany (SWEDMARK, 1958) and the Isle of Man (MILLER, 1963) (Fig. 3: 5, 6 respectively).

When the available data for both *P. microps* and *P. minutus* is considered in relation to sea surface temperature in the southern Boreal region and Baltic Sea (Fig. 3), there emerges a probable correlation between occurrence of migration and minimal winter temperatures. Offshore migration has been recorded in areas where winter temperatures normally fall below 5°C, but has not been found to take place in waters above 7°C. In this connection, the difference in behaviour of *P. microps* in Castletown Bay, Isle of Man, and Morecambe Bay may be explained in terms of the sharp decline in surface temperature across the eastern Irish Sea in winter.

At certain localities experiencing a minimum sea surface temperature of less than 5°C, namely Aberlady Bay (Fig. 3: 2) on the Firth of Forth (NICOL, 1935) and the Bas Escaut (LELOUP & KONIETZKO, 1956), populations of *P. microps* are known to occupy saltmarsh or brackish shore pools over winter, just as a small proportion of the Heysham gobies seems to remain in the pools during this season in

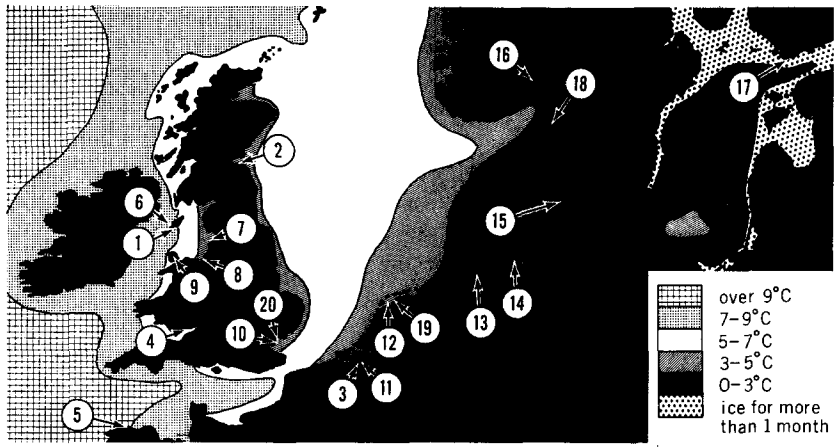

Fig. 3. Occurrence of winter migrations in *P. microps* and *P. minutus* in relation to minimum winter sea surface temperatures (February) for southern Boreal and Baltic Sea areas. Hydrographic data from SCHULZ (1932) and BOWDEN (1955), as in key. Migration occurs at localities 7—17 (*P. microps*) and 18—20 (*P. minutus*); non-migration at 1—4 (*P. microps*) and 5 and 6 (*P. minutus*). Further information and authorities cited in text.

most years. With colonies inhabiting very high saltmarsh pools, the opportunity to migrate in autumn may be not only determined by frequency of tidal inundation but might also be affected if suitably high tides coincided with a short period of mild weather, when the appropriate stimulus of falling autumn temperatures would be temporarily lacking. Such fishes may be killed when the pools are frozen in the subsequent winter (LELOUP & KONIETZKO, 1956). In a more extreme case of isolation, HOWES (1939) found that *P. microps* (recorded as "*Gobius minutus*") was common in a saline lagoon in south east Essex which had been separated from the sea for nine years – the considerable size of this body of water (2.5 km long, 50—75 m wide, maximum depth over 3 m) could well have permitted migration into deeper water in winter when surface temperatures probably fell below 0°C in most years.

Especially for populations inhabiting the belt of intermediate minimum winter temperatures (5°C—7°C) along much of the west coast of Great Britain, the occurrence and extent of migration may be expected to depend on annual variations in these winter sea temperatures. In July 1963, one of us (PJM) found adult *P. microps* to be fairly common in pools at Oxwich, near Swansea. These fishes had undoubtedly been spawned in the previous spring or summer, and had thus survived the exceptionally severe winter of 1962—63, when shores in the area were frozen and considerable mortality of intertidal

organisms resulted (CRISP *et al.*, 1964). It may be assumed that the species was able to persist in the area by sublittoral migration in response to the adverse climatic conditions, just as did shore fishes along the north Wales coast during the same winter (CRISP *et al.*, 1964). However, migration at this time of year on the south Wales coast may not normally be very extensive, since the species is known to be present at high water on Lamby saltmarsh, near Cardiff, during the normal winter (BROUGH, DELHANTY & THOMPSON, 1964). This case does serve to illustrate that, with species such as *P. microps* and *P. minutus*, which belong to the southern element of the British fish-fauna, the capacity to react to low temperatures by migration into somewhat warmer water is of obvious adaptive importance in the penetration of colder inshore parts of the boreal region, quite apart from any increased physiological resistance to cold which may be developed.

Under conditions of abnormally low temperatures, the limit of this ability to withstand cold may be reached and populations considerably reduced or exterminated. This has already been noted for saltmarshes (LELOUP & KONIETZKO, 1956) but on a larger scale appears to have occurred during the severe winter of 1962—63 at Morecambe (D.J., personal observation) and also in the Waddensea (M. FONDS, personal communication). At Morecambe, during 1963, adult *P. microps* did not appear on the mussel beds in spring and only seven such fishes were found throughout the summer. Although no nests were observed on the shore, juveniles began to occur in pools towards the end of July and continued to be numerous until November, when the usual winter migration from the shore took place. In the Waddensea, following severe winters in both 1962—63 and 1963—64, the end of July and continued to be numerous until November, winter sublittoral habitats and on the shore in summer. Because of the short life cycle of this species, with maturation after the first winter of life, a level of population size comparable to that previously found in such an area could be fairly quickly restored, given a succession of normal winters. Assuming recolonisation in the summer after the severe winter by adequate numbers of postlarvae, a breeding population, derived from these, could be reestablished there after only one milder winter.

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SUMMARY

Seasonal changes in abundance, and also reproduction, of the gobiid *Pomatoschistus microps* in intertidal pools on mussel beds at Morecambe, Lancashire, were studied from 1956 to 1961. During winter the shore was largely vacated by this species which returned for breeding purposes in spring. Spawning took place in upper shore pools from April to August. After a planktonic life of between 6—9 weeks, young fishes were recruited to the demersal population usually from June to September. A correlation between seasonal migrations and sea temperature is postulated. Geographical variation in occurrence and extent of migration in *P. microps* and the related sublittoral *P. minutus* is considered in relation to minimum winter sea temperatures over the southern Boreal and Baltic sea areas. Offshore winter migration has been found to take place in areas where such temperatures normally fall below 5° C, but not where minimum sea temperature is above 7° C. The effect of the severe winter of 1962—63 on certain populations of *P. microps* is described.

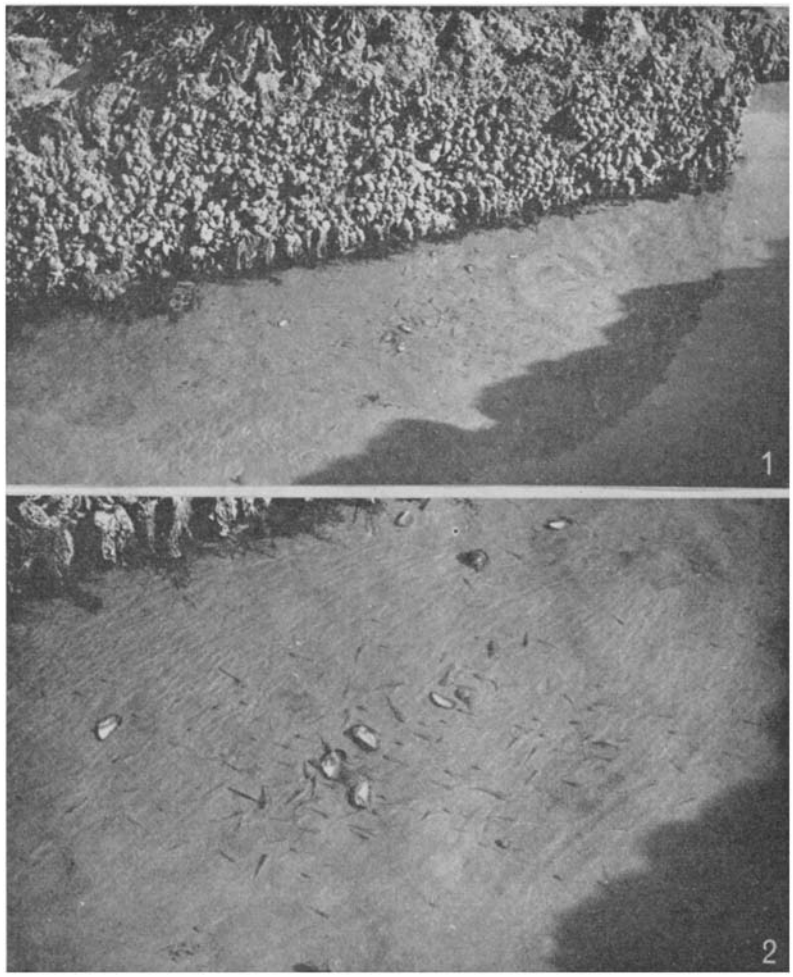

Plate I:

Fig. 1. Edge of large pool on upper Heysham Flat, below HWN, 23 Sept. 1960, showing exposed bank of mussels and numerous *P. microps* over sandy bed of pool.

Fig. 2. Closer view of *P. microps* in same pool, showing mostly juveniles but with several larger individuals which were probably adults. The gobies were attracted by the opened mussels which the authors threw into the pool.

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