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THE DISTRIBUTION OF *MYTILUS EDULIS* AND ANOMIID LARVAE IN KILKIERAN BAY, CO. GALWAY.

BY

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The distribution of *Mytilus edulis* and Anomiid Larvae in Kilkieran Bay, Co. Galway

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ABSTRACT

The temporal and spatial distribution of *Mytilus edulis* and Anomiidae larvae were recorded in Kilkieran Bay, Co. Galway, during 1984 and 1985. Only larvae close to settlement (*M. edulis* larvae > 250 μm length and Anomiid larvae > 160 μm length) were considered. *M. edulis* larvae were commonest in late July, mid-August and early September 1984 and in early May, mid-June and early September 1985, while Anomiid larvae were commonest in late June and mid-July 1984 and mid-June and early September 1985. *M. edulis* larvae were generally found in higher densities at the mouth of the bay, while Anomiids were more evenly dispersed with high concentrations over the oyster beds. There was no significant ($P < 0.05$) net import of either species of larvae into the bay over tidal cycles.

INTRODUCTION

Substrates attractive for mussel settlement are kept to a minimum on well maintained productive oyster beds, but on poorly managed beds, especially where strong currents prevail, accumulation of suitable substrates can encourage the establishment of small colonies of mussels and the gradual development of mussel banks (Maas Geesteranus, 1942; De Blok and Geelin, 1958). This in turn leads to direct fouling of oysters by mussel seed and increased sedimentation (Verwey, 1952) with consequent detrimental effects to the fishery.

Extensive oyster beds occupy the upper reaches of Kilkieran Bay, Co. Galway, which in recent years have been fished sporadically (Barry, 1975, 1976 and 1977). Management of these beds has been limited to control of starfish predators by periodical mop-dredging and spreading of mussel shell cultch in the summer months to improve the intensity of spat settlement. The beds have a muddy marl substrate which has been overgrown in many areas by *Zostera* spp and filamentous algae. Two species of saddle-oysters, the common saddle-oyster, *Anomia ephippium*, and the ribbed saddle-oyster, *Pododesmus (=Monia) patelliformis*, are particularly abundant on the beds, and compete with oyster spat for settlement sites on shell and other suitable substrates, while increasing the grazing pressure on phytoplankton stocks. *Mytilus edulis* is found in isolated patches on rocks and ropes on the fringes of the beds, but the densest populations are to be found on rocky islands at the mouth of the bay, where some commercial suspended culture of mussels is also carried out.

Objectives of the present study were to describe temporal and spatial distributions of larvae of *M. edulis* and of Anomiids in general in Kilkieran Bay, to identify the areas where major accumulations of mature larvae occur and to examine the factors influencing the distribution of larvae in the neighbourhood of the oyster beds. A potential mechanism for recruitment of *M. edulis* to the beds was developed by these means and compared with the strategy adopted by the established Anomiid competitors.

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MATERIALS AND METHODS

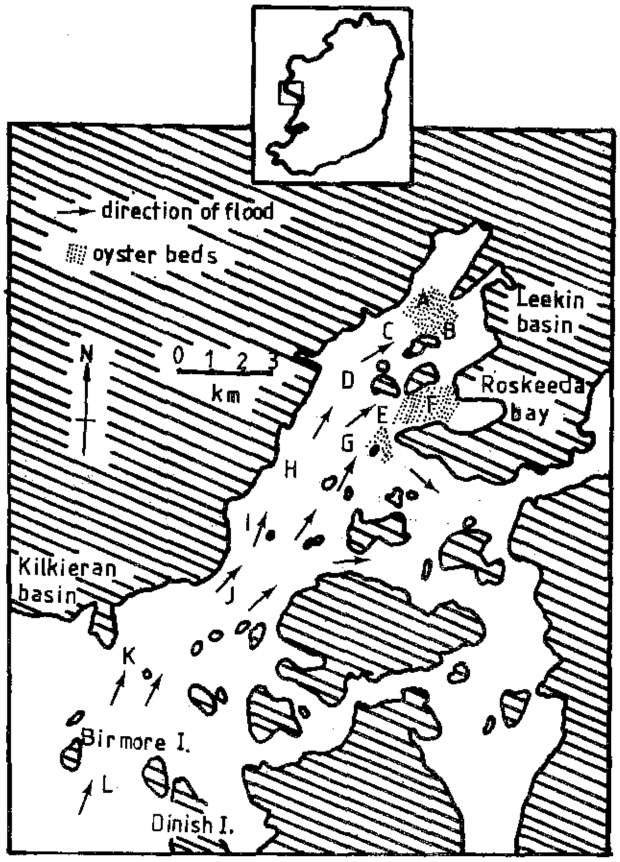

Fig. 1. A map of Kilkieran Bay showing the sampling sites.

Kilkieran Bay is almost 12km long and encompasses about 6000 ha including three major basins; the Leekin basin, Roskeeda Bay, and the outer Kilkieran Basin (Fig. 1). A channel connecting these basins is situated on the western side of the bay with an outlet to the sea between Birmore and Dinish Islands to the south. Salinities are generally between 33 and 35 ppt., but during prolonged rainfall freshwater run-off from the surrounding land can reduce salinities in the upper reaches to 26-27 ppt. The temperature and salinity regimes in areas on and near the oyster beds for 1984 and 1985 have been described by Wilson (in prep.). The volume of water at low water in the inner bay, that is the area contained by a line drawn between Birmore and Dinish Islands, as calculated by cartographic survey is estimated as 2.61×10^8 m^3. The tidal prism increases this by about 50% at mean high water. Depths are generally between 2—10m, with the bottom gently shelving to 25m at the mouth. Oyster beds lie in 1—3m of water in the Leekin basin and in Roskeeda bay.

Larval sampling.

Larval samples were collected in 1984 and 1985 from 30 May to 11 September and 24 April to 2 October respectively. During 1984 sampling was carried out at low water $\pm$1h at 10 stations (A—J; Fig. 1), while in 1985 samples were taken at high water $\pm$ 1 h at 6 stations (E, H, I, J, K and L; Fig. 1).

Samples were collected in 1984 using a hand-operated pump calibrated to deliver 100 l water samples, which were taken at 5m intervals from surface to bottom at each station. Samples were pumped through 90 µm mesh plankton net squares which were stored in 10% neutralised formalin.

In 1985 larval samples were collected with 90 µm mesh, 400 mm mouth diameter conical plankton nets. Vertical oblique tows were made from a stationary boat by lowering the weighted net to the bottom and hauling it a measured distance to the surface. The amount of water filtered was quantified with a flowmeter in the net mouth. Between 3.2m^3 and 4.9m^3 were filtered during tows. Samples were stored in 10% neutral formalin. Samples were concentrated in the laboratory by gentle stirring, bivalve larvae were identified (Rees, 1950) and individual shell lengths measured. Counts were made of Anomiid and *M. edulis* larvae near settlement and additionally mussel plantigrades i.e. *M. edulis* > 240 um length and Anomiids > 160 µm lengths. The use of the term *"M. edulis larva"* in this paper therefore includes stages before and after primary settlement up to shell lengths of about 450 µm.

Larval fluxes

Import and export of larvae to and from the bay were examined in 1985 by measurement of larval fluxes over 12 h tidal cycles at a station at the mouth of the bay halfway between Birmore and Dinish Islands. Samples were collected and readings made every hour for 12 h during both spring and neap tides respectively on 6 and 24 May, 6 and 21 June and spring tides on 5 July. Larvae were collected by vertical/oblique hauls with a 90 µm mesh plankton net as described above. Current speed and direction were recorded concurrently with a flowmeter at 5 m depth intervals.

The instantaneous flux of larvae was calculated as:

$$F_T = V \times W \times D \times C$$

where F_T is the instantaneous flux, V is the depth-averaged instanteous velocity, W and D are the width and depth of the partial cross-section of the transect respectively and C is the concentration of larvae at the station.

The net flux calculated for each tidal series was obtained by expressing instantaneous flux as a function of time (T):

$$F_T = F_N + a \times \sin(2\pi T/12.42)$$

where F_T is the instantaneous flux, F_N is the net flux and a is a coefficient. Negative fluxes represent exports and positive fluxes imports. A Student's t test was used to test the null hypothesis $F_N = O$ ($P < 0.05$) for each tidal cycle.

RESULTS

M. edulis larval concentrations in 1984 and 1985.

Larvae of *M. edulis* were infrequently found in samples in 1984 and 1985 in the Leekin basin or in the inner part of Roskeeda Bay in 1984 (stations A, B, C, D and F). Concentrations of larvae taken from Stations E, H, I and J in 1984 and E, H, I, J, K and L in 1985 are plotted in Figs. 2 and 3 respectively. The mean concentrations of larvae calculated as the average number of larvae collected

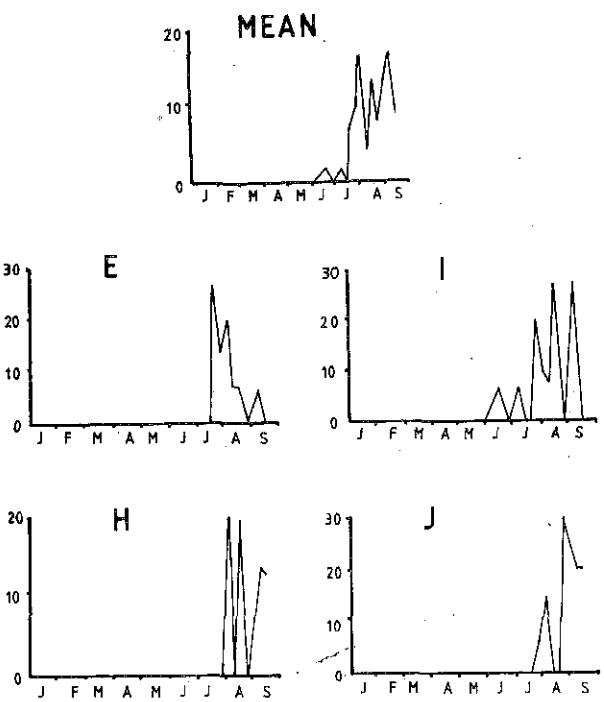

Fig. 2. Concentrations of M. edulis larvae (larvae m^{-3}) taken from stations E, H, I and J in 1984. The mean concentrations of larvae calculated as the average number of larvae collected on each sampling date at the four stations in 1984 are also shown.

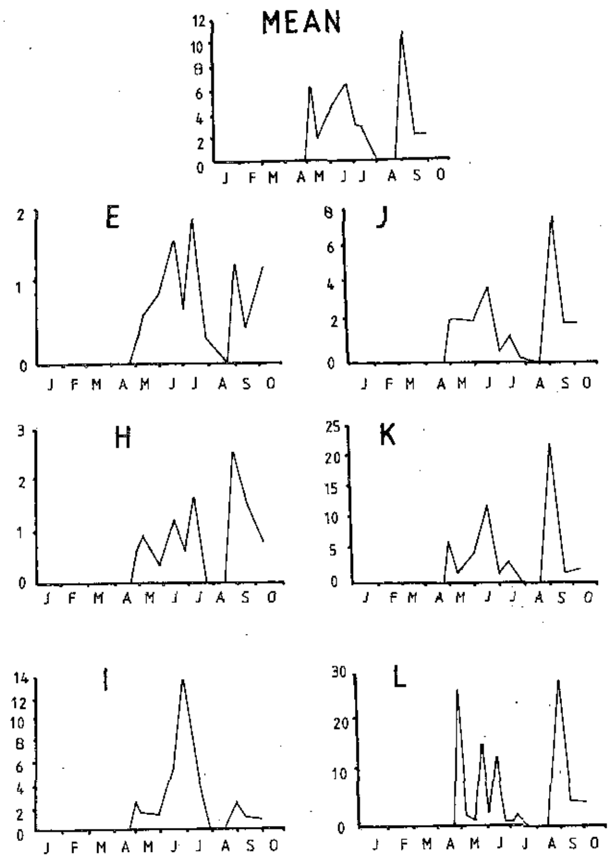

Fig. 3. Concentrations of M. edulis larvae (larvae m^{-3}) taken from stations E, H, I, J, K and L in 1985. The mean concentrations of larvae calculated as the average number of larvae collected on each sampling date at the six stations in 1985 are also shown.

on each sampling date at the four stations in 1984 and six stations in 1985 are also shown. Peaks in the temporal distribution of *M. edulis* larvae were recorded in 1984 in late July, mid August and early September, while in 1985 they occurred in early May, mid June and early September. Larval concentrations were lower in the 1985 season with average numbers not exceeding 11 larvae m^{-3} (30 August) as opposed to a maximum of 16.25 larvae m^{-3} (11 September) in 1984

It is apparent from Figs. 2 and 3 that larval concentrations varied from station to station on each sampling date. Larval concentrations recorded at each station were expressed as annual means (Table 1) to facilitate comparisons between stations. Counts from all 10 stations in 1984 and 6 stations in 1985 were incorporated. Mean concentrations of mussel larvae tended to be higher in stations to the seaward of the oyster beds in 1984 and 1985.

Anomiid larval concentrations in 1984 and 1985.

Anomiid larvae were found in samples at all stations in 1984 and 1985. For comparative purposes concentrations of larvae taken from the same stations where *M. edulis* larvae were common (E, H, I and J in 1984 and E, H, I, J, K and L in 1985) are plotted in Figs. 4 and 5 respectively. The mean concentrations of larvae calculated as the average number of larvae collected on each sampling date at the four stations in 1984 and six stations in 1985 are also shown. Peaks in the concentration of Anomiid larvae were recorded in 1984 in late June and mid-July, while in 1985 they occured in mid June and early September. Larval concentrations were much higher in the 1985 season with average numbers reaching 116 larvae m^{-3} (11 September) compared with a maximum of 8 larvae m^{-3} (17 July) in 1984.

Spatial distributions of Anomiid larvae were analysed as above by means of the annual mean concentrations at each station (Table 1). Counts from all 10 stations in 1984 and 6 stations in 1985

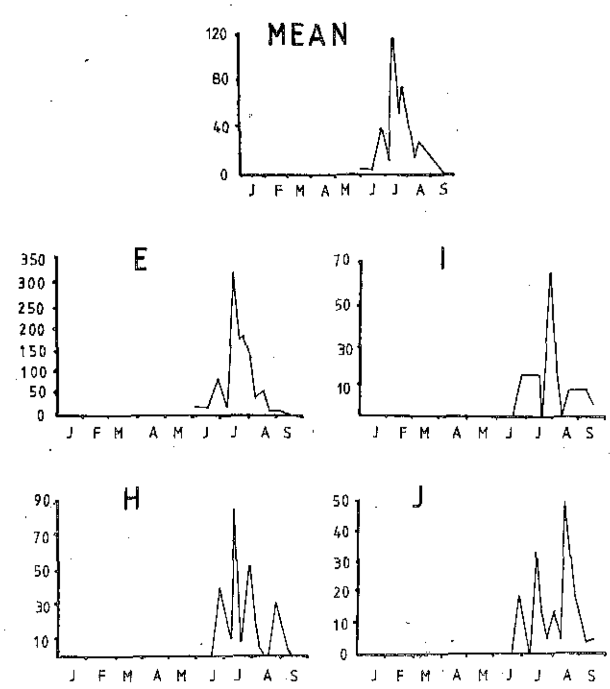

Fig. 4. Concentrations of Anomiid larvae (larvae m^{-3}) taken from stations E, H, I and J in 1984 where M. edulis larvae were common. The mean concentrations of larvae calculated as the average number of larvae collected on each sampling date at the six stations in 1985 are also shown.

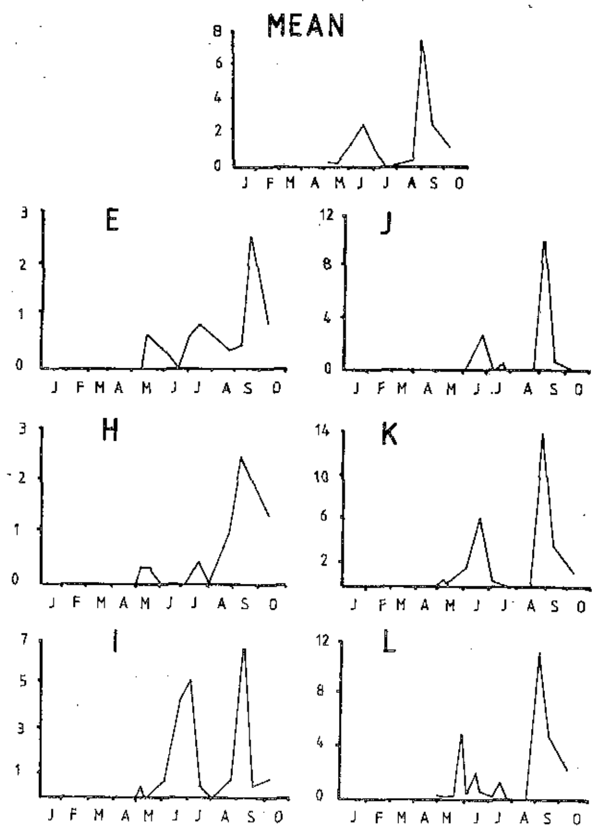

Fig. 5. Concentrations of Anomiid larvae (larvae m^{-3}) taken from stations E, H, I, J, K and L in 1985 where M. edulis larvae were common. The mean concentrations of larvae calculated as the average number of larvae collected on each sampling date at the six stations in 1985 are also shown.

were incorporated. In 1984 the highest mean concentration was at station E on the Roskeeda oyster bed being almost six times greater than at the most seaward station (J). In 1985 the concentrations were much lower than in 1984 the overall mean concentration being 1.49 larvae m^{-3} compared with 34.62 larvae m^{-3} in 1984. There was a slight increase in numbers down the bay but the differences between most stations were small. Wilson (in prep.) has shown that in 1985 heavy rainfall led to displacement of oyster larvae down the bay. The same low salinities may have caused a similar displacement of Anomiid larvae in 1985.

M. edulis larval fluxes at the Dinish-Birmore station.

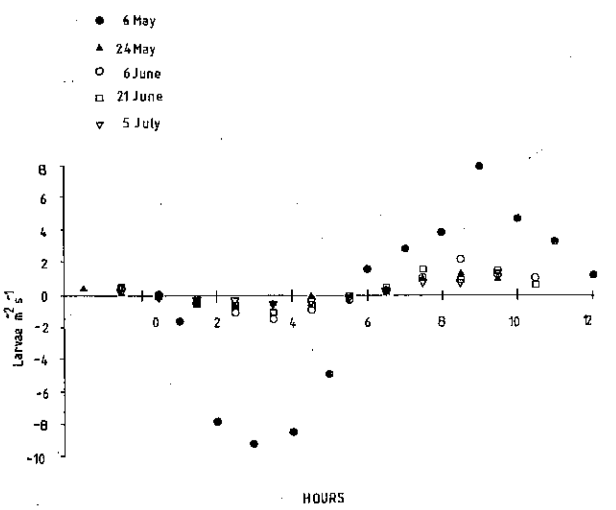

Fig. 6. The instantaneous fluxes of M. edulis larvae recorded every hour across the Dinish-Birmore station during each of the five tidal cycles. Hour 0 and 12 represent high water and hour 6 low water.

The instantaneous fluxes of *M. edulis* larvae recorded every hour across the Dinish-Birmore station during each of the five tidal cycles are shown in Fig. 6. Hour 0 and 12 represent high water and hour 6 low water. Flux has been expressed as number of larvae m^{-2} s^{-1}. As instantaneous flux is a function of current speed as well as larval concentration it tends to be maximal at mid-tide and approaches 0 at low and high water. The high current velocity in conjunction with high larval concentrations on 6 May gave higher than usual instantaneous fluxes approaching 10 larvae m^{-2} s^{-1} at mid-tide but generally instantaneous fluxes rarely exceeded 2 larvae m^{-2} s^{-1}. The net *M. edulis* larval fluxes together with net or residual currents are given in Table 2. Both net currents and *M. edulis* net fluxes were relatively small and were not significantly different from 0 ($P < 0.05$).

Anomiid larval fluxes at the Dinish-Birmore station

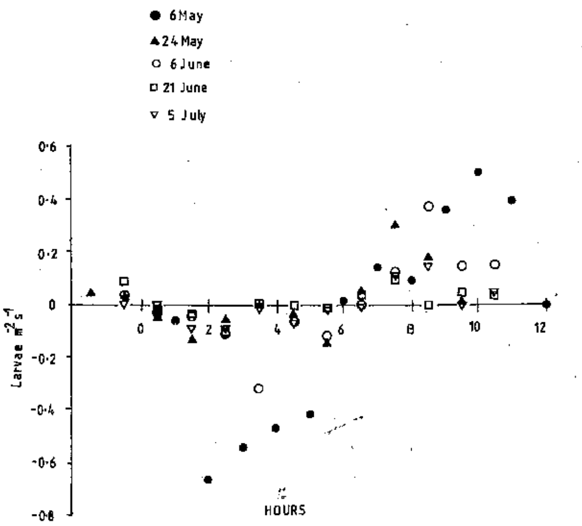

Fig. 7. The instantaneous fluxes of Anomiid larvae recorded every hour across the Dinish-Birmore station during each of the five tidal cycles. Hour 0 and 12 represent high water and hour 6 low water.

Instantaneous Anomiid fluxes followed the same cyclical pattern as those of *M. edulis* but were much lower and did not exceed 0.8 larvae m^{-2} s^{-1} (Fig. 7). Net fluxes again were very small and were not significantly ($P < 0.05$) different from 0 (Table 2).

Relative concentrations of M. edulis and Anomiid larvae during cycles.

The mean concentrations of *M. edulis* and Anomiid larvae during each 12 h cycle are given in Table 3. Variations in counts from hour to hour were relatively minor in most cycles but on the 6 May cycle variances exceeded means for both larval types indicating over-dispersion or "patchiness" in the larval distributions being sampled. In Table 3 coefficients of dispersion (Cassie, 1962) have been included to indicate the degree of overdispersion in samples. Positive coefficients are indicative of overdispersion as on 6 May.

A comparison was made between the relative concentrations of Anomiid larvae and *M. edulis* larvae recorded at each hour of each of the 12 h cycles. Larval concentrations for each hour were first expressed as percentages of the 12 summed larval counts for each 12 h cycle. The percentage of Anomiid larvae was compared with the corresponding percentage of *M. edulis* larvae recorded in the same hour of each cycle using the nonparametric Wilcoxon Matched Pairs Test. This showed that there was a significant difference ($P < 0.05$) between *M. edulis* and Anomiid percentage concentrations for each hour during all of the five 12 h cycles. Furthermore stepwise comparisions with the Wilcoxon Paired Rank Test showed that there was no significant ($P < 0.05$) similarity between cycles in the temporal distribution of relative concentrations of the same larval type (*M. edulis* or Anomiid larvae). Hence there was no specific periods during tidal cycles when the presence of peaks in concentration of either larval type could be predicted at the Dinish-Birmore station.

DISCUSSION

M. edulis larvae were extant over the outer area of the Roskeeda oyster beds during the 1984 and 1985 seasons. Their numbers were relatively low peaking at around 30 larvae m^{-3} in 1985. Jenkins (1979) has noted that concentrations of more than about 30 mature *Perna canaliculus* larvae m^{-3} will usually give a settlement such as is desirable in mussel farming operations. It is possible that mussel larvae infrequently settle in large numbers on suitable substrates on the beds in Roskeeda Bay. Those mussels that do settle are probably rapidly removed by predators such as starfish and crabs. In some areas of Roskeeda the presence of dense clumps of adult mussels of similar size on ropes where predation pressures are less tends to support this conclusion. Seed (1969) has found that the abundance of predators sub-littorally usually prevents the establishment of long lived populations and leads to rapid turnover of mussels. It would follow that control of oyster predators on the beds may in turn increase the risk of mussel infestation.

The origin of these larvae must be in areas to the seaward of the oyster beds. There is a gradual but significant increase in the concentration of *M. edulis* larvae down the bay, which is related to the abundance of littoral mussel stocks and possibly mussel farming operations. The very low concentrations of larvae taken at low water in 1984 and the higher levels in the high water samples of 1985 suggests that larvae are imported from the outer bay on flood tides. It has been shown that mussel larvae pass into the bay at up to 10 larvae m^{-2} s^{-1} at mid tide. Assuming that the instantaneous flux is uniform throughout the total cross section of the mouth of the bay this represents a transport through the mouth of the bay of approximately 7×10^8 mussel larvae h^{-1}. While these or other larvae are exported on the ebb, Wilson (in prep.) has shown that oyster larvae can be carried to the upper reaches of the bay and to the oyster beds from the Dinish-Birmore station on tidal excursions. An increase of mussel stocks in the outer bay would undoubtedly generate an increase in the number of mussel larvae entering the inner bay during tidal excursions, and an increased risk of the colonisation of the oyster beds.

There is a large population of Anomiids in the bay which generate a large number of larvae especially on and near the oyster beds. Peaks in larval concentrations were recorded in late June and mid-July in 1984 and mid-June and early September 1985. Kilroy (1979) found that *Anomia ephippium* larvae were particularly common in August and September in Lough Ine, SW Ireland, and Ebling *et al.* (1948) found the heaviest settlement to be in September. Seed (1982) recorded spawning in *A. ephippium* in June and July, while *Padodesmus patelliformis* partially spawned in May and more fully in August and September on the NE coast of Ireland. The early larvae in Kilkieran Bay may, therefore, have been mainly *P. patelliformis,* while those later in the year mainly *A. ephippium.*

The spatial distribution of Anomiid larvae in the bay is more homogeneous than that of *M. edulis* (except on 6 May) as a consequence of the widespread distribution of the parent stock. Import ation of Anomiids from the outer bay is insignificant. Control of Anomiid numbers would therefore be difficult and labour intensive. The maximum concentration of Anomiid larvae recorded during the 1984 and 1985 surveys was 320 larvae m^{-3} on 12 July 1984 at the Roskeeda station (station E). Wilson (in prep.) recorded the maximum *Ostrea edulis* concentration of all sizes as 840 larvae m^{-3} on 7 August 1984 at Roskeeda approximately 2.6 times the number of oyster larvae as Anomiids. However only 4.4% of the oyster larvae in August 1984 were >250 µm so that only some 37 oyster larvae m^{-3} were near settlement as opposed to 8.6 times that number of Anomiids during their peak in July 1984. There was clearly a potentially massive occupation of suitable settlement sites by Anomiids prior to the main oyster settlement. Considering the settlement times of the two species it would be expedient to spread cultch for oyster settlement subsequent to the main Anomiid settlement, but as oyster settlement also occurs in early July (Wilson; in prep.) the benefits might be minimal.

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Table 1. Annual mean concentrations (larvae m^{-3}) and standard deviations of the mean for *M. edulis* and Anomiid larvae for 10 stations in 1984 and 1985.

Stations	*M. edulis* (larvae m^{-3})		Anomiid (larvae m^{-3})	
	1984	1985	1984	1985
A	0.00 ± 0.00	–	33.85 ± 43.50	–
B	0.00 ± 0.00	–	36.92 ± 43.09	–
C	2.22 ± 6.67	–	47.69 ± 53.88	–
D	7.78 ± 13.02	–	27.69 ± 34.92	–
E	8.87 ± 9.41	0.77 ± 0.62	77.94 ± 96.20	0.59 ± 0.68
F	4.44 ± 8.82	–	30.77 ± 30.13	–
G	2.22 ± 6.67		43.08 ± 43.85	–
H	10.36 ± 8.23	2.54 ± 6.32	19.48 ± 26.87	0.65 ± 0.88
I	10.52 ± 9.51	2.90 ± 3.82	15.37 ± 15.10	1.67 ± 2.38
J	6.84 ± 8.92	1.98 ± 2.14	13.38 ± 15.10	1.33 ± 3.05
K	–	4.71 ± 6.58	–	2.38 ± 4.03
L	–	8.49 ± 10.46	–	2.31 ± 3.47
MEANS	5.33 ± 8.65	3.56 ± 6.26	34.62 ± 47.95	1.49 ± 2.72

Table 2. Net *M. edulis* and Anomiid larval fluxes (no. m^{-2} s^{-1}) together with net currents ($m\ s^{-1}$) recorded during the five tidal cycles. Standard deviations of F_N and correlation coefficients (r) for the regression $F_T = F_N + a \times \sin(2\pi T/12.42)$ are included, where T is the sampling time, F_T is the instantaneous flux, F_N is the net flux and a is a coefficient.

Date	Net current	Net *M. edulis* flux	Net Anomiid flux
6 May	0.042 ± 0.023	−0.530 ± 0.440	−0.052 ± 0.002
	r = −0.99	r = −0.96	r = −0.94
24 May	0.027 ± 0.029	0.160 ± 0.097	0.007 ± 0.001
	r = −0.90	r = −0.87	r = −0.73
6 June	0.037 ± 0.015	0.170 ± 0.047	0.015 ± 0.001
	r = −0.99	r = −0.95	r = −0.88
21 June	0.020 ± 0.006	−0.554 ± 0.36	−0.022 ± 0.001
	r = 0.97	r = −0.61	r = −0.88
5 July	0.075 ± 0.032	0.169 ± 0.046	0.005 ± 0.229
	r = −0.95	r = −0.96	r = −0.77

Table 3. The mean concentration (larvae m^{-3}) and variance of the mean for *M. edulis* and Anomiid larvae during each 12 cycle. The coefficient of dispersion ($\hat{C}$) is given by

$$\hat{C} = (s^2 - m)/m^2$$

where s is the standard deviation of the mean and m is the mean.

	M. edulis			Anomiid		
Date	m	s^2	$\hat{C}$	m	s^2	$\hat{C}$
6 May	11.53	23.91	0.09	8.33	36.24	0.43
24 May	2.01	1.59	−0.10	0.59	0.12	−1.35
6 June	3.83	2.37	−0.10	0.43	0.06	−1.98
21 June	3.11	1.37	−0.18	0.21	0.04	−3.78
5 July	1.43	0.40	−0.50	0.19	0.02	−4.77

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