ECOLOGY OF PLAICE (*PLEURONECTES PLATESSA*) IN FISH ASSEMBLAGES OF BEACHES OF THE OPALE COAST (NORTH OF FRANCE) DURING SPRING 1997

by

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ABSTRACT. - In recent years, many studies on the ecology of demersal populations nurseries have focussed on subtidal areas and estuaries, whereas the intertidal zone, especially sandy beaches, have been more or less neglected. Weekly sampling was carried out over 7 weeks in spring 1997, at three intertidal beaches (Merlimont, Wissant and Oye-plage) along the Opale Coast. The aim was to determine whether the intertidal zone is of any ecological importance for flatfish. Sampling was achieved with a standard beam trawl, as the one used by local fishermen. Each sampled site showed low diversity of the ichthyofauna and was dominated by the plaice, *Pleuronectes platessa* and the shrimp, *Crangon crangon*. Analysis of plaice abundance and size distribution showed differences among beaches throughout time. To the south, succession of cohorts was observed whereas a weekly settlement is suggested for the northern beaches. The variability of plaice settlement dynamics in those areas might be influenced by temperature and tides as well as by mutual predation between young plaice and shrimp, which influence the plaice dynamics. This study shows the role of sandy beaches as an ecosystem temporally occupied by young flatfish throughout this period of their life cycle.

RÉSUMÉ. - Écologie de la plie (*Pleuronectes platessa*) dans les assemblages de poissons des plages de la côte d'Opale (nord de la France) au printemps 1997.

Ces dernières années, de nombreuses études sur les nourriceries des poissons nectobenthiques ont été concentrées sur les zones subtidales et les estuaires, plutôt que sur leur composante intertidale : les plages sableuses. Cette étude porte sur le rôle écologique de la zone intertidale pour les poissons plats. L'échantillonnage a été mené au printemps 1997, durant 7 semaines, sur 3 plages de la Côte d'Opale : Merlimont, Wissant et Oye-plage. Il a été réalisé à l'aide d'un chalut à perche standardisé, couramment utilisé par les pêcheurs à pieds. Chacun des sites a montré une faible diversité de l'ichtyofaune et était dominé par la présence de la plie, *Pleuronectes platessa*, et de la crevette, *Crangon crangon*. L'analyse de la densité et des compositions en taille des plies a montré des différences entre les plages sur la période considérée. Ainsi, au sud de la zone étudiée, plusieurs groupes successifs d'individus ont pu être mis en évidence. Au nord, sur les deux autres sites, une dynamique de renouvellement permanent des individus a été observée. Cette étude montre le rôle de la zone médio-littorale des plages sableuses, comme étant un écosystème colonisé temporairement par les jeunes plies durant une étape de leur vie. La dynamique de cette espèce en zone littorale dépend de facteurs abiotiques (température, coefficient de marée) et de la prédation mutuelle avec les crevettes.

Key words. - Pleuronectidae - *Pleuronectes platessa* - France - Opale Coast - Nursery - Sandy intertidal beaches - Juveniles.

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Intertidal beach is the uppermost part of the coastal belt. It is characterised by the tidal immersion and impacts of wave and storm. The high biological productivity is favourable for benthic macro-fauna and juveniles of commercial fish species (Lackey and Nielsen, 1980; Costa, 1986). Numerous studies focus on the ecology of estuaries and bays along the Atlantic and English Channel / North Sea coast (Kuipers, 1973, 1977; Rijnsdorp *et al*., 1985; Van der Veer, 1986; Safran, 1987; Marchand and Masson, 1989; Amara *et al*., 1993). Few refer to open-sandy beach despite their importance for the growth of the new settlers (Berghahn, 1987; Ansell and Gibson, 1990; Burrows *et al*., 1994).

The present study concerns three sandy beaches on the Opale coast (from Belgium boundary to Bay of Somme), situated along the French side of the Eastern English Channel and the southern Bight of the North Sea (Fig. 1). This area is governed by a northerly tidal residual current (1.7 to 3.4 km/day) from the English Channel to the North Sea enhanced by frequent south-western wind (Salomon and Breton, 1991) with high amplitude semi-diurnal tides (8 m maximum tidal range). Near the coast, the tidal stream is strong (5.5 to 6.5 km/h during spring tide) (Anonymous, 1968), alternating and parallel to the coast. In the English Channel, the coast to offshore gradient is associated to the tidal residual current and acts like a barrier for fish larvae (Grioche and Koubbi, 1997). This structure does not remain along the North Sea coast.

These beaches are classified in the second group, according to Short (1991), with non-uniform slope (> 1°), sand ripples, bars and pools (2 to 5) parallel to the coast (Fig. 2a). This morphology induces an alternative movement of swash-backwash (Guilcher, 1954; Chamley, 1987) in the same direction as the residual tidal current. Fine and medium sands dominate the strand. It is more muddy to the east of Calais (Clabaut and Chamley, 1986; Cuisinet *et al*., 1986), and more coarse to the west of Calais (Davoult, 1983; Dewarumez, 1987). This characterises a soft intertidal sediment benthic community.

This work focussed on the dynamics of the intertidal nursery of plaice, *Pleuronectes platessa* L., during spring, in the main process of turbulent diffusion from the spawning area, in the English Channel, to the nursery (Talbot, 1978). Plaice juveniles prefer a bare sandy substratum (Wennhage and Pihl, 1994) with depth of few meters (Riley *et al*., 1981; Van der Veer and Witte, 1993; Burrows *et al*., 1994). Consequently, we chose to sample on three

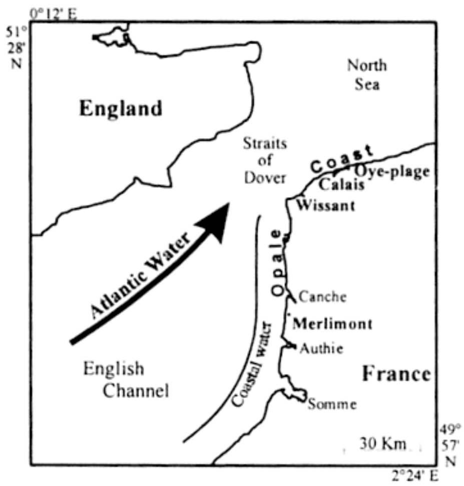


Fig. 1. Location of the three sampling sites (Merlimont, Wissant, Oye-plage). Location of the major estuaries along the Opale Coast.

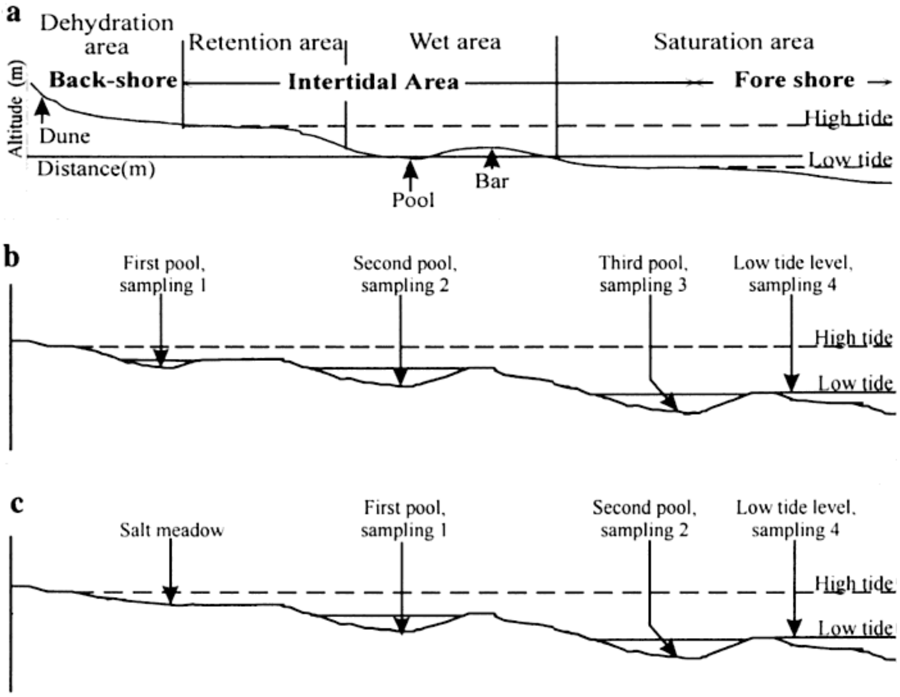


Fig. 2. Sections of sandy beaches of the Opale Coast. **a**: Typical section; **b**: Scheme for Merlimont and Wissant beaches, showing the levels of sampling during the survey and sampling numbers used in the analysis; **c**: Scheme of Oye-plage beach, showing the levels of sampling during the survey.

nursery areas to underline their characteristics for the early life stages of fish. Our main objective was to explore spatio-temporal variations of fish assemblages in comparison with known studies on the subtidal zone (Anonymous, 1993). We try to show that these narrow and fragile intertidal areas play a role for juvenile fish.

MATERIALS AND METHODS

Sampling

Weekly surveys were carried out on the three beaches, Merlimont, Wissant and Oye-plage, from the 13th of May to the 2nd of July 1997 except for one-week (Table 1). The sampling occurred during daytime to avoid dial influence, 4 hours before low tide until low tide. Three pools at Merlimont and Wissant and two on Oye-plage were sampled at different times on the falling tide (Fig. 2). Their depth varied from 0.30 to 1 m. A standard beam shrimp net, 3 m long and 2 m wide, with a stretched mesh size of 12 mm in the main body and 10 mm in the codend was used (Riley *et al.*, 1981; Péronnet and Tétard, 1984; Safran, 1987). Two men dragged it for 20-min. Fished samples were fixed in 5% formaldehyde seawater buffered with sodium tetraborate to the seawater pH. All fishes were identified and measured. Catch per hour of fishing was then calculated. Shrimps were recorded on the basis of total shrimp biomass. At all stations, sea temperature was measured and sediment taken to evaluate the granulometry *So* (Trask's index) and the porosity *Iv* (Griffith, 1967).

Data analyses

Standard length distribution (SL) of plaice was tested by a two way - ANOVA among beaches and between levels.

A multiple correspondence analysis (MCA) was computed on the 72 observations using the plaice abundance, ranked by occurrence, links to the environmental factors (tidal range and seawater temperature) and shrimp biomass. Each variable was divided into 4 classes by taking quartiles and median.

From the coordinates of descriptors and observations on the first five axes, Euclidean distances and dendrograms were computed using the flexible clustering ([illegible] = −0.3) as already used on the MCA by Koubbi *et al.* (1991). Groups were identified and reported on the MCA factorial planes. Consequently, relationships between the abundance of plaice and the weight of shrimps can be analysed according to abiotic factors (temperature, tidal range).

Finally, the population dynamics of plaice on the three beaches was studied with a correspondence analysis (COA) on the fish abundance per standard length classes. The boundaries were defined using 6 iso-frequency classes (1.4 to 3.0 cm, 3.0 to 3.8 cm, 3.8 to 4.2 cm, 4.2 to 4.8 cm, 4.8 to 8.0 cm and 8.0 to 16.0 cm). Both multivariate analyses, due to the barycentric plot, allows a simultaneous representation of variables and descriptors.

RESULTS

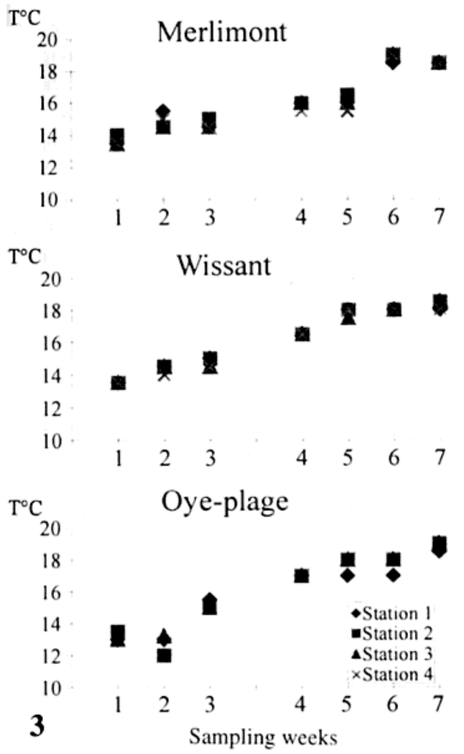
Abiotic factors

Seawater temperature increased from 13.5°C to 19°C from on the 13th of May to 2nd of July 1997 (Fig. 3). There were slight differences between stations on the same beach and between beaches.

For sediments of these beaches the Trask's index (*So)* was between 1 and 1.5, indicating a well-dispersed deposit. The porosity coefficient (*Iv*) was equal to 0.11. Both indexes define a similar biotop, which represents probably the same available epibenthic food to fishes and also means a similar hydrodynamism in the dynamics of bars and pools over the three open sandy beaches.

Table 1 - Chronology of sampling during spring 1997, the hour of sampling and tidal range. It is necessary to take about one hour before or after into consideration, according to the position of sampling. The tidal range is calculated with the height of water, included from 20 to 120.

Sample	Merlimont (4 stations)			Wissant (4 stations)			Oye-plage (3 stations)		
1	13 May	10h00	51	14 May	11h00	43	16 May	14h00	40
2	20 May	17h00	76	22 May	18h00	88	24 May	15h00	92
3	30 May	12h00	60	28 May	10h00	67	29 May	12h00	62
4	13 June	11h00	43	10 June	10h00	48	12 June	13h00	48
5	21 June	18h00	93	16 June	14h00	65	19 June	18h00	77
6	27 June	10h00	71	25 June	10h00	86	24 June	11h00	87
7	02 July	17h00	73	01 July	16h00	65	30 June	15h00	61



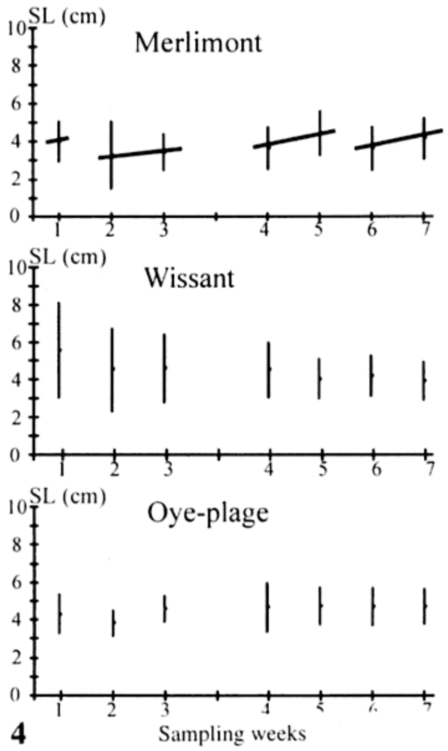


Fig. 3. Temporal evolution of Sea water temperature by beach and during spring 1997.
Fig. 4. Mean standard length (SL) and standard deviation of plaice by beach and sampling weeks. ——— : Identification of cohorts.

Species and size distribution

Eighteen species were caught. Rank-frequency tables (Table I) show slight differences in the community of each beach. The plaice was the dominant species with 75-80% at each station at this season. The highest abundance (Table II) was found at Merlimont whereas it was equal elsewhere. An increase of the abundance of plaice throughout the survey was also observed, particularly for the last two weeks.

Standard length analysis shows a north to south significant difference (ANOVA, $p < 0.05$) with mean largest fish at Oye-plage (4.60 cm ± 0.86 cm SD) followed by Wissant (4.49 cm ± 1.38 cm SD) and at Merlimont (3.80 cm ± 0.95 cm SD) (Table II). Size difference between levels is also shown (ANOVA, $p < 0.05$), with the smallest fish in the highest pool. Size cohorts could be identified for Merlimont, but constant sizes were observed elsewhere (Fig. 4).

Multiple Correspondence Analysis on plaice abundance

The first two factorial axes explained more than 32% of the total inertia. Latent roots were 0.55 and 0.13 respectively.

The first dendrogram was created on descriptors with classes of the biotic and abiotic factors. Four clusters are observed (Fig. 5). The group A is opposite to group D separating the lowest temperature and tidal range from the highest ones. The highest abundance of plaice and the highest biomass of shrimps are clustered (group A) against their lowest values in-group D. The two others clusters, B and C, show medium values for the abiotic and biotic factors. Comparison of clusters C and D show within group opposition of the shrimp biomass and plaice abundance: highest abundance of plaice was separated from highest biomass of shrimp.

The second dendrogram was created from MCA observation coordinates. The first axis shows a temporal pattern by discriminating the abundance classes from May to June (Fig. 6). Four groups were identified. Group I gathers observations from the beginning of the survey, from the 13th to the 30th of May. Group II corresponds to the end of the survey, from the 27th of June to the 2nd of July. The two other cluster III and IV are in between.

Table II. – Percentage of total catches per beach.

Merlimont		Wissant		Oye-plage	
Species	**Percentage**	**Species**	**Percentage**	**Species**	**Percentage**
Pleuronectes platessa	79.62%	*Pleuronectes platessa*	75.23%	*Pleuronectes platessa*	76.69%
Sprattus sprattus	12.62%	*Hyperoplus lanceolatus*	7.87%	*Sprattus sprattus*	11.82%
Gobius spp.	3.34%	*Echiichthys vipera*	7.59%	*Pleuronectes flesus*	4.68%
Hyperoplus lanceolatus	1.33%	*Sprattus sprattus*	4.59%	*Psetta maxima*	1.97%
Echiichthys vipera	1.27%	*Gasterosteus aculeatus*	1.50%	*Syngnathus acus*	1.97%
Solea solea	0.42%	*Pleuronectes flesus*	1.16%	*Scophthalmus rhombus*	1.89%
Scophthalmus rhombus	0.37%	*Scophthalmus rhombus*	0.84%	*Echiichthys vipera*	0.42%
Psetta maxima	0.28%	*Psetta maxima*	0.66%	*Hyperoplus lanceolatus*	0.24%
Limanda limanda	0.18%	*Solea solea*	0.28%	*Gobius* spp.	0.16%
Syngnathus acus	0.16%	*Limanda limanda*	0.19%	*Gasterosteus aculeatus*	0.08%
Pleuronectes flesus	0.15%	*Agonus cataphractus*	0.09%	*Gadus morhua*	0.08%
Agonus cataphractus	0.14%	*Gadus morhua*	> 0.01%	*Cottus gobio*	> 0.01%
Lampetra spp.	0.04%	*Cottus gobio*	> 0.01%	*Raja clavata*	> 0.01%
Cottus gobio	0.03%	*Raja clavata*	> 0.01%	*Lampetra* spp.	> 0.01%
Raja clavata	0.03%	*Syngnathus acus*	> 0.01%	*Merlangius merlangus*	> 0.01%
Merlangius merlangus	0.03%	*Gobius* spp.	0.00%	*Limanda limanda*	0.00%
Gasterosteus aculeatus	> 0.01%	*Lampetra* spp.	0.00%	*Agonus cataphractus*	0.00%
Gadus morhua	0.00%	*Merlangius merlangus*	0.00%	*Solea solea*	0.00%

Table III. – Summary table of the number of fish and their mean size collected during the survey.

	Merlimont		Wissant		Oye-plage	
Sample	**Nb of fish per hour**	**Size (mm)**	**Nb of fish per hour**	**Size (mm)**	**Nb of fish per hour**	**Size (mm)**
1	225	4.02 ± 1.06	114	5.66 ± 1.82	111	4.27 ± 1.02
2	603	3.28 ± 1.79	156	4.50 ± 2.20	147	3.96 ± 0.58
3	315	3.45 ± 0.93	180	4.61 ± 1.80	135	4.62 ± 0.68
4	444	3.63 ± 1.09	336	4.54 ± 1.46	384	4.78 ± 1.30
5	495	4.45 ± 1.15	240	4.03 ± 1.02	276	4.88 ± 0.99
6	3708	3.62 ± 1.10	675	4.15 ± 0.99	516	4.85 ± 0.98
7	2145	4.16 ± 1.07	369	3.94 ± 1.07	669	4.81 ± 0.95
	Σ = 7935	$\overline{x}$ = 3.80 ± 0.95 SD	Σ = 2070	$\overline{x}$ = 4.49 ± 1.38 SD	Σ = 2238	$\overline{x}$ = 4.60 ± 0.86 SD

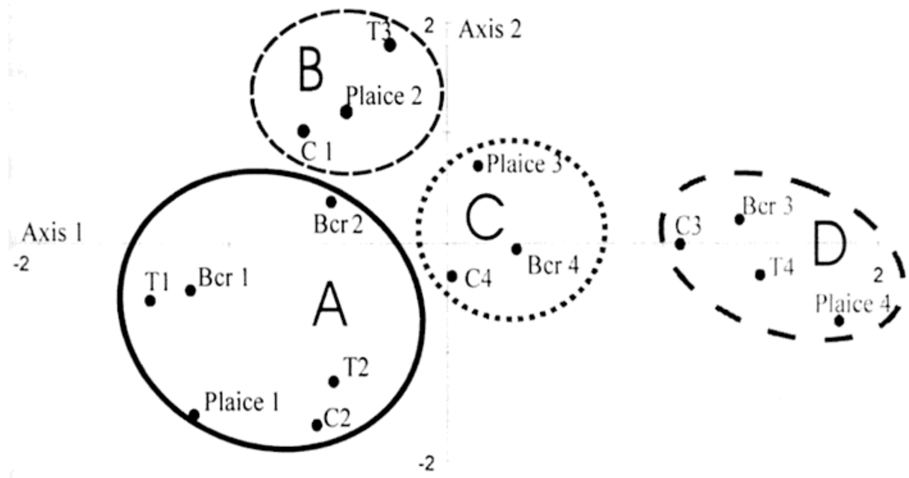


Fig. [illegible]. Factorial plane 1-2 (32% of the total inertia) of the MCA on classes of plaice abundance (see below); Bcr: Shrimp biomass; T: Seawater temperature; C: Tidal range. Groups derived from the clustering of variable coordinates are shown (A to D):

		Class 1	Class 2	Class 3	Class 4
Biotic variables	Number of plaice juvenile per hour of fishing	< 47	47 - 100	100 - 200	> 200
	Shrimp biomass caught per hour (g)	< 367	367 - 888	888 - 1862	> 1862
Environmental parameters	Tidal range (from 20 to 120)	< 51	51 - 65	65 - 77	> 77
	Seawater temperature (°C)	< 14.5	14.5 - 16	16 - 18	> 18

Correspondence Analysis on plaice standard length

The Correspondence Analysis (COA) was computed on 5 descriptors (standard length classes) and 71 observations. The two first axes gather 80% of the total inertia and the first axis is about 63% (Fig. [illegible]). The axis 1 shows a standard length gradient from the smallest fish at the right (C1), to the largest fish at the left (C5).

For Merlimont the plot of observations do not show a temporal pattern, because of the succession of cohorts (Fig. [illegible]) but indicate a difference in size between levels. Low levels (4), are mainly plotted in the left part of the plane, well separated from the other ones. At Wissant (Fig. [illegible]), there is a spatial pattern, noting that fishes of same size are found at the same level. At Oye-plage, there is a temporal pattern (Fig. [illegible]) separating the two first weeks on the right side of the graph from the other surveys. No spatial pattern is observed except for the first two surveys.

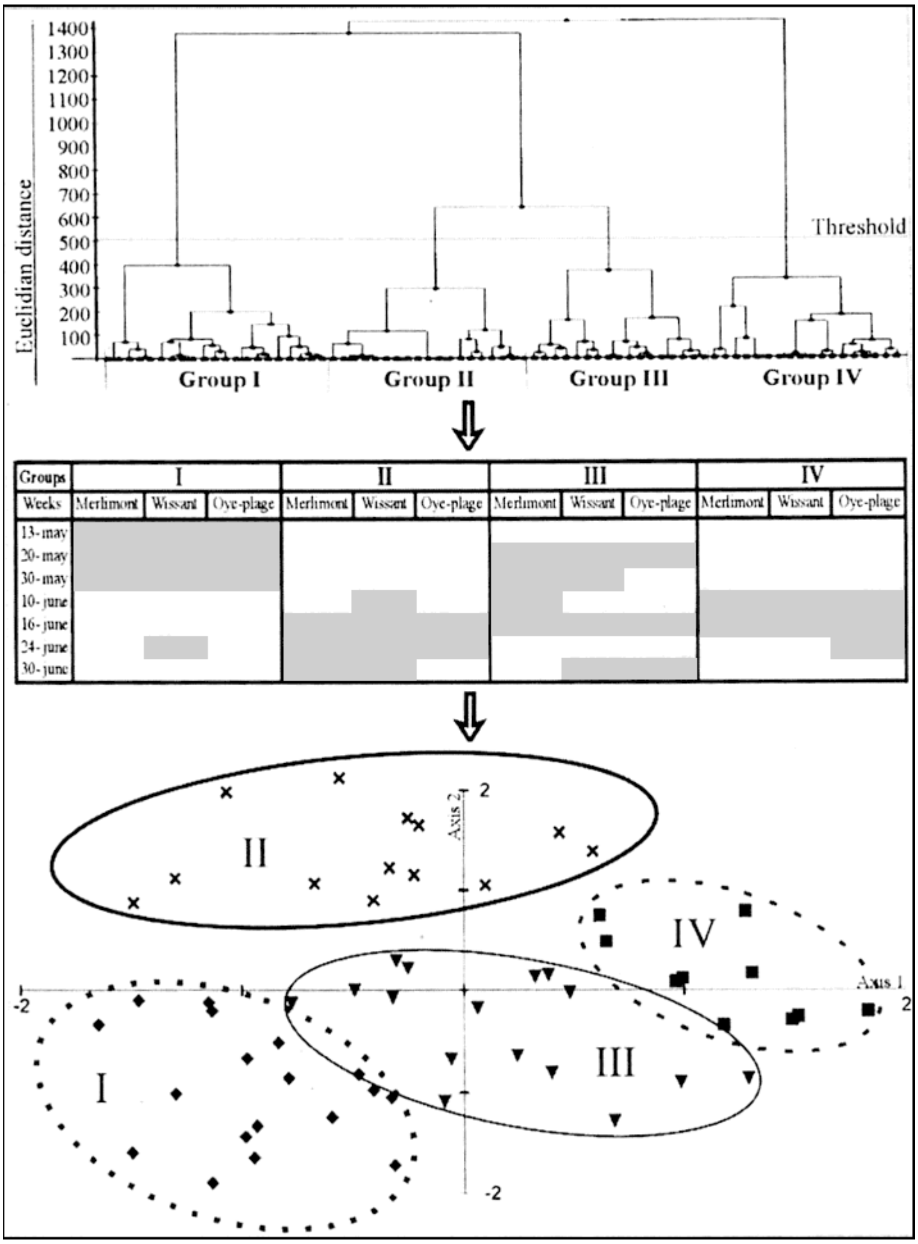


Fig. 6. – Factorial plane 1-2 (32% of the total inertia) of the MCA showing observations. Groups derived from the clustering of observation coordinates by a dendrogram are shown (I to IV). The table shows the stations belonging to each group. Groups are plotted on the factorial plane.

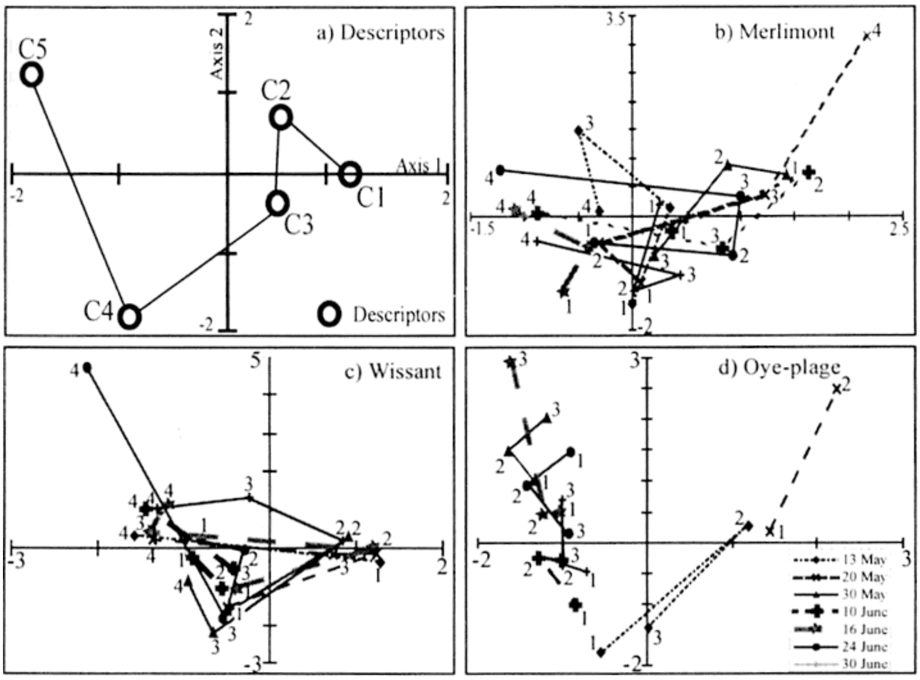


Fig. 7. Observation in the factorial plane 1-2 of the COA on the standard length classes. The first axis contributes to 18.5% and the second contributed to 13.7% of the total inertia. According to the weeks and the level (1 to 4). **a**: Plot of the descriptors (standard length classes; C1: smallest to C5: largest). Plot of observations for each sampling date for: **b**: Merlimont; **c**: Wissant; **d**: Oye-Plage.

DISCUSSION

The settlement of plaice juveniles in the intertidal area was followed from May to July. The three beaches have more or less the same physiognomy and sediments (same granulometry and porosity indexes) and even similar communities. Nevertheless, differences between beaches were pointed out for the plaice juveniles. These are essentially due to others variables, like the geographical location, the position of the pool on the beach and the period of the season. Temporally, our results corroborate Safran's work (1987) showing a succession of cohorts on the same nursery areas for the English Channel (Merlimont).

Abundance

P. platessa was the most dominant species (75% of collected individuals). It shows an increase in abundance over time on the three beaches. This might be related to the rise of the sea water temperature and the tidal currents. Indeed, early-juveniles join the nurseries with the tidal currents and acquire a selective tidal behaviour (Talbot, 1978; Rijnsdorp *et al.*, 1985; Bergman *et al.*, 1989; Metcalfe *et al.*, 1990). This is corroborated with the MCA on plaice abundance, which shows maximum abundance, linked to high tidal range. In opposite, low abundance, as recorded during May might be explained by the presence of the phytoplanktonic bloom of *Phaeocystis* sp., which makes the strand anoxic and less nutritive because of the presence of mucus and dead cells (Claustre *et al.*, 1990).

The correspondence analysis on plaice sizes on the three beaches shows different structures: Merlimont with a heterogeneous distribution of standard length, Wissant with a spatial structure and Oye-plage temporally structured. Abundance appears greater at Merlimont, which is located between two estuaries (Authie and Canche). This beach is on the path of a coastal water mass, directed northward and lying parallel to the coast (Brylinski *et al.*, 1991) favourable for concentrating fish larvae (Grioche *et al.*, 1997). This result may be linked to the biomass of benthic organisms, which depends directly on estuarine influences as shown by Gregoire (1976) and Davoult (1983). Standard length distribution over time showed a succession of cohorts through spring probably linked to inputs of new settlers from the English Channel spawning area (Harding and Talbot, 1973; Van der Land, 1991). A different pattern is shown for North Sea beaches for which we observe a continual replacement of individuals of the same size. In fact, on the two beaches, a residual drift from west to east is observed (Clabaut and Chamley, 1986; Anonymous, 1996). These observations are confirmed with the growth rate, 0.16 mm/day for larvae, determined by Ehrlich *et al.* (1976) or till 0.8 mm/day for juvenile (Poxton *et al.*, 1983; Alhossaini and Pitcher, 1988; Modin and Pihl, 1994; Nash and Geffen, 1999). No standard length increase is noted on Wissant and Oye-Plage opposite to the different cohorts at Merlimont. The residual northern drift is responsible of mixing and smoothing of cohorts, in the northern part. Moreover, the main direction of wind is southwesterly that implies a frontal impact with the English Channel French coast whereas the wind is parallel to the North Sea coast. It supplies these areas with plaice larvae from the English Channel (Harding and Talbot, 1973; Harding *et al.*, 1978, Talbot, 1978; Hovenkamp, 1989).

Tidal migration

Commonly, a difference in size between levels is noted. High pools and lowest levels are often related to the largest fish whereas intermediate were related to the smallest fishes (Fig. 8). This is an artefact of our sampling strategy, easily explained by literature. Largest fishes were sampled at high shore level at the beginning of the ebb. They were not found later in intermediate levels, which suggests that they might react rapidly to pressure decrease. Gibson (1992) describes this phenomenon for young individuals, which respond to the hydrostatic pressure by escaping the intertidal area. These older fishes can be considered as temporally cyclic resident of the intertidal zone. Whereas smallest individuals may stay in intermediate pools during low tide, largest plaice returned rapidly to subtidal during ebb. Moreover, it seems that the 0-group plaice live in the intertidal waters and move progressively into the subtidal area during their growth as observed by Gibson (1973).

These movements probably correspond to behaviour of avoidance for predation and competition. On these open sandy beaches, the shrimp was the prey and predator of plaice so both species play a major role in the trophic web of these areas (Thijssen *et al.*, 1974; Wennhage and Gibson, 1998). The MCA that showed for 2 groups (A and D, Fig. 5) that medium abundance of plaice is inversely correlated to the biomass of shrimp. *C. crangon* is known to be the principal predator of plaice with size less than 30 mm (Van der Veer and Bergman, 1987; Ansell and Gibson, 1993). Even if the predation by the shrimp is considered as one of the regulation factors of the density between the different nurseries (Van der Veer, 1986; Pihl, 1990), the reciprocal predation by the plaice still exists. As results show, shrimp biomass decreases when plaice abundance increases. This indicates an interaction between plaice and shrimp, as a mutual predation.

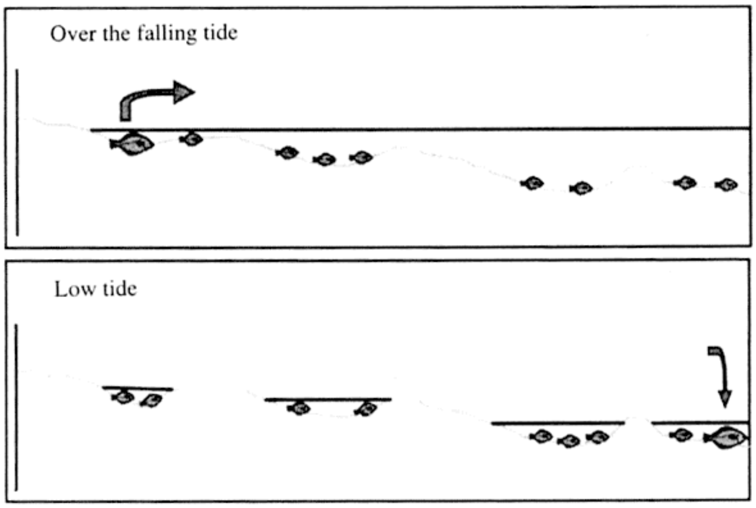


Fig. 8. Hypothetical scheme of the movement of plaice juveniles on the intertidal area, during the tide. The largest plaice leave the high levels with the tide, whereas the smallest ones remain in the different pools.

The dominant species in the intertidal area is plaice, whereas simultaneously sampled with the same gear, dab (*Limanda limanda*) is dominant in the subtidal area (Safran, 1987; Burrows *et al.*, 1994; Amara, unpubl.). This may indicate a spatial segregation of species along the strand and supports the conclusions of Safran (1987), who described a guild composed by the dab, the plaice and the sole, occurring throughout the year in this area. This pattern may avoid interspecific competition (Ansell and Gibson, 1990). Moreover, it was shown that plaice larvae and juvenile are able to use a tidal migration unlike dab (Gibson, 1973; Poxton *et al.*, 1982; Rinjsdorp *et al.*, 1985; Burrows *et al.*, 1994).

Though, with regard to the numerous catches of plaice in this area, it appears that juveniles make intertidal movements because the abundance of food, favourable for their growth (Kuipers, 1973; Berghahn, 1987), is free from competition of other fish species.

Then, we confirm that some juveniles, for their life cycle, remain necessary and temporary in the strand during the daytime. Numerous studies, on continuous sloping beaches or without considering pools, focus a dial and tidal migration in the Wadden Sea (Kuipers, 1973; Van der Veer and Bergman, 1986; Berghahn, 1987; Burrows *et al.*, 1994), on the west coast beaches (Gibson, 1973; Ansell and Gibson, 1990, 1993; Gibson, 1992; Nash and Geffen, 1999) or in the North Sea (Harding *et al.*, 1978; Rijnsdorp *et al.*, 1985; Pihl, 1990). Nevertheless, the beaches of the Opale Coast seem to be an intermediate system, with a specific replacement dynamic and distribution of individuals. The studied whole can fit into different tidal flats. For instance the migration on the Merlimont beach seems to be similar at the observations on the Wadden Sea, while on beach of Wissant or Oye-plage are more similar at the 'west coast' beaches. That shows us the capacity of species to adapt to the physical conditions of the strand due to the tide and currents.

In conclusion, the population dynamics with succession of cohorts and a system of dynamic replacement, with a size gradient on the beaches show that strands form an important habitat for plaice juveniles. As described by Rijnsdorp *et al.* (1985), young plaice come from the English Channel and go to the North Sea, carried by the residual drift through the Straits of Dover. Moreover, the young plaice adopt a migration strategy that permits a growth in optimal conditions. Individuals present a “behavioural homeostasis” (Rountree and Able, 1992). The 0-group plaice accomplish movements in the intertidal area where the temperature is optimal (□ 20°C) (Edwards *et al.*, 1969), like in our study. Secondly, they avoid a high predation and minimise the feeding competition with the other species, *Limanda limanda*, *Carcinus maenas* and *Crangon crangon*, as sandy beaches has abundant supra-benthic preys.

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