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## LONG-TERM CHANGES IN THE STRUCTURE OF UNDERWATER MEADOWS OF THE PUCK LAGOON

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Considerable changes in the structure of phytobenthos occurred in the Puck Lagoon in the last 32 years. *Furcellaria lumbricalis* Lyngb. and *Fucus vesiculosus* L., previously represented in the Lagoon very abundantly, are absent at present. Up to 70% of the total biomass of the benthic vegetation are contributed by the Ectocarpaceae which grew for about 3.5 months in 1988, i.e. from April until mid-July.

### INTRODUCTION

Long-term studies carried out by numerous authors showed substantial changes to have occurred in the structure of and spatial coverage by the phytobenthos of the Puck Lagoon in the past (Ciszewski et al. 1962; Ciszewski 1963; Klekot 1980; Pliński 1982; Błędzki and Kruk-Dowgiałło 1982). The present study was carried out within the framework of the "Restoration of the Puck Lagoon" project and seeks to describe some qualitative and quantitative changes which took place in the area during 1979–1987. Aerial observations and underwater exploration were used during the study. Additionally, a comparative analysis of temporal changes in the spatial coverage by 5 phytobenthic species typical of the Puck Lagoon is presented.

### MATERIALS AND METHODS

Studies on qualitative and quantitative changes in phytobenthos of the Puck Lagoon were carried out in 1979 and 1987. The quantitative changes were estimated from the phytobenthos biomass. Samples for the biomass estimation were collected at 22 stations in 1979 and at 28 stations in 1988 (Fig. 1). Divers sampled the phytobenthos from within bottom areas marked out by a 1 m<sup>2</sup> frame (Ciszewski 1963).

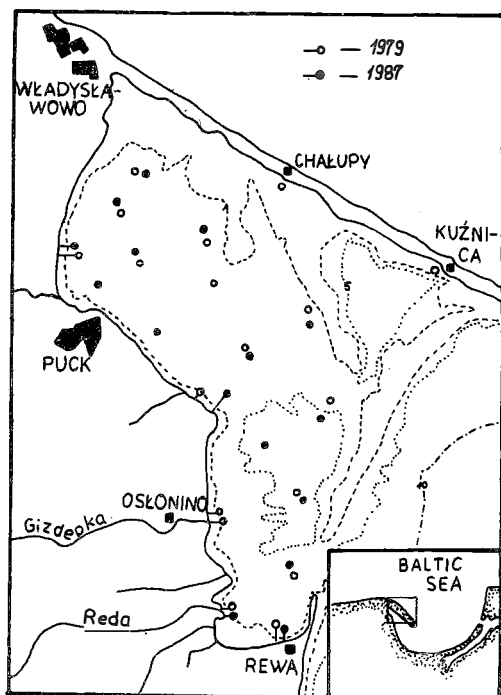


Fig. 1. Location of sampling sites in the Puck Lagoon

After sorting and identification of the phytobenthic species, the samples were processed to obtain biomass data in terms of dry weight, following Dybern et al. (1976). Qualitative changes in the phytobenthos were estimated from samples collected by divers and with a dredge. The extent of the underwater meadows was estimated based on reconnaissances made by divers at 3-wk intervals in 1988. First, the canopy of the Ectocarpaceae and their growth period were estimated. As of April 1989, aerial photographs of the underwater meadows were taken once a month.

## RESULTS

The following phytobenthic species were found in the Puck Lagoon in 1979 and 1987:

	1979	1987
1. <i>Enteromorpha prolifera</i> J.G.Ag.	+	+
2. <i>E. interstitialis</i> Link	+	+
3. <i>Cladophora glomerata</i> Kutz.	+	+
4. <i>Tolypella nidifica</i> v. Leonh.	+	+

	1979	1987
5. <i>Chara baltica</i> Bruzelius	+	+
6. <i>Pilayella littoralis</i> Kjellm.	+	+
7. <i>Ectocarpus siliculosus</i> Dillv	+	+
8. <i>Furcellaria lumbricalis</i> (Huds.) Lamour.	+	—
9. <i>Phyllophora brodiaei</i> J.G.Ag.	+	—
10. <i>Ceramium tenuicorne</i> Waern.	+	—
11. <i>Potamogeton perfoliatus</i> L.	+	+
12. <i>P. filiformis</i> Persoon	+	+
13. <i>Zostera marina</i> L.	+	+
14. <i>Ruppia rostellata</i> Koch	+	+
15. <i>Zannichellia palustris</i> L.	+	+
16. <i>Myriophyllum spicatum</i> L.	+	+

(+ denotes presence and — denotes absence of a species).

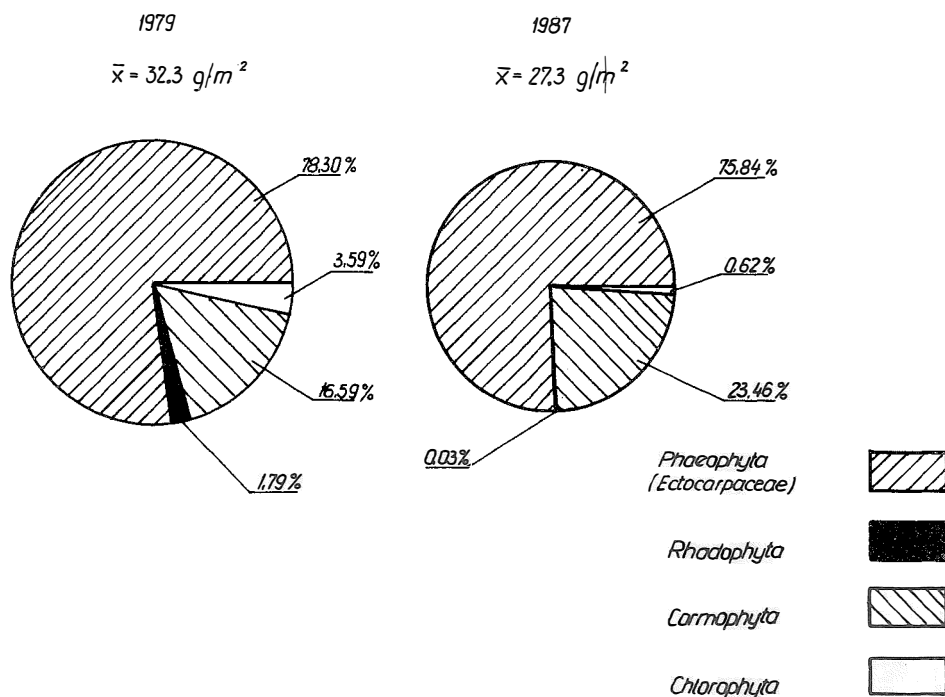


Fig. 2. Partitioning of the mean biomass ( $\bar{x}$ ) of phytobenthos in the Puck Lagoon in 1979 and 1987

The quantitative and qualitative structure of the phytobenthos were found to have changed to a certain degree within the period of the nine years. *Furcellaria lumbricalis* and *Phyllophora brodiaei* were not observed in 1987. On the one hand, a 15.6% decrease in the phytobenthos biomass occurred (Fig. 2), while on the other, a slight

increase in the Ectocarpaceae biomass took place at the same time; the brown alga predominated in terms of biomass in the Puck Lagoon both in 1979 and in 1987. In 1987, there was also an increase in the *Cormophyta* biomass, primarily due to an increase in *Zannichellia palustris*. Underwater observations showed that this vascular plant species co-occurs at present with the *Ectocarpaceae* almost on the whole bottom of the Puck Lagoon. The underwater and airborne reconnaissances made in 1988 and 1989, respectively, showed the *Ectocarpaceae* to begin developing in early April when the water temperature is 8°C. The maximum growth of the algae takes place in the turn of May and June; they die off and mineralize in July until August, depending on the water temperature. Thus, the growth period of the Ectocarpaceae is of short duration (3.5 months).

## DISCUSSION

Changes in the taxonomic structure of phytobenthos have been observed in various coastal water areas of the Baltic (Kangas et al. 1982). Such changes are particularly apparent in the Puck Lagoon and they are both qualitative and quantitative in nature (Biedzki and Kruk-Dówgiałło 1983). The spatial cover by the underwater meadows which contained numerous algal species in the past, has been reduced. *Fucus vesiculosus* and *Furcellaria lumbricalis* used to densely cover the bottom of the Lagoon in the

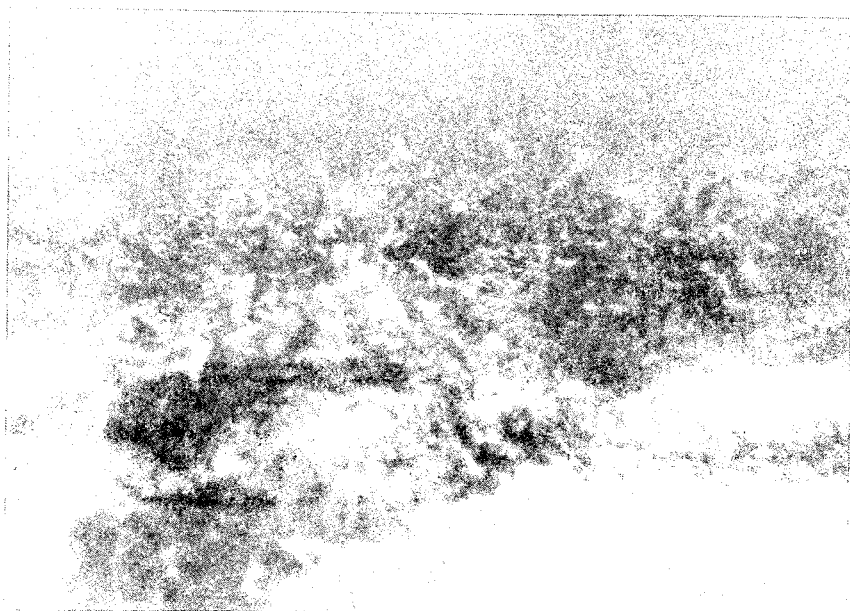


Photo 1. Underwater meadows (*Fucus vesiculosus*) in 1957 (Photo: P. Ciszewski)

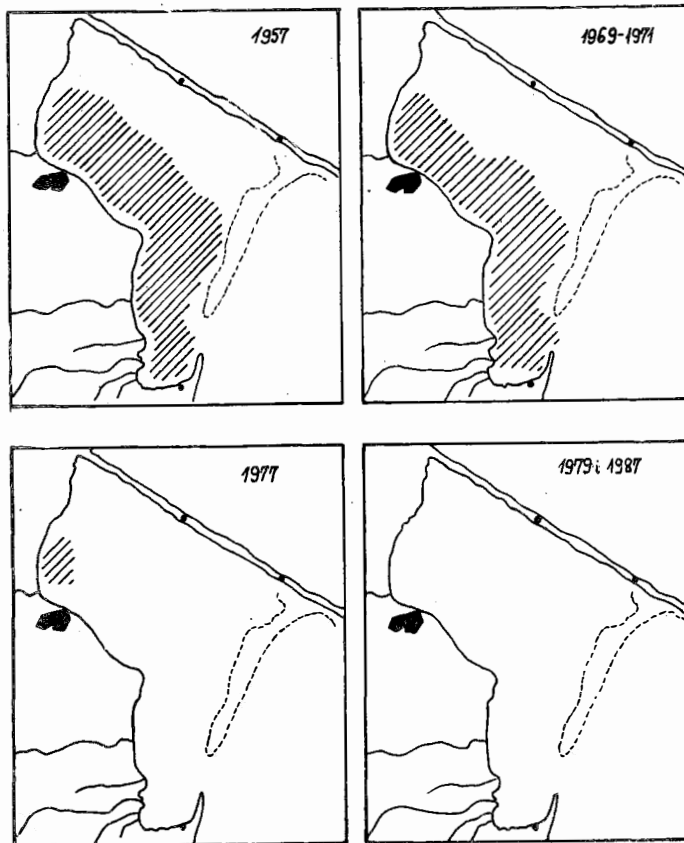


Fig. 3. Changes in distribution of *Fucus vesiculosus* L. in the Puck Lagoon, as revealed by comparison of data collected in 1957 (Ciszewski 1962), 1969–1971 (Klekot 1980), 1977 (Pliński 1982), 1979 and 1987 (this study)

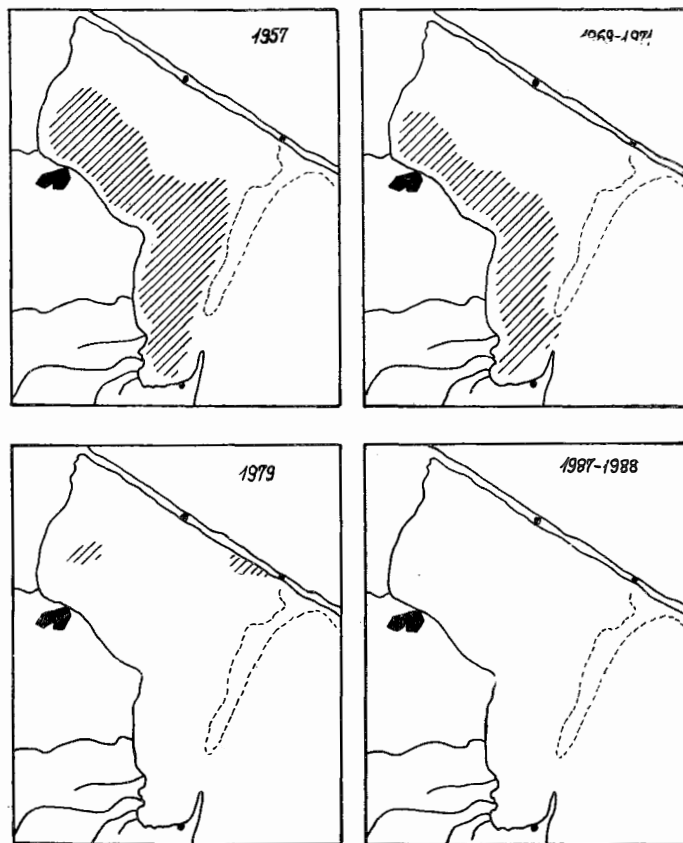


Fig. 4. Changes in distribution of *Furcellaria lumbricalis* Lyngb. in the Puck Lagoon, as revealed by comparison of data collected in 1957 (Ciszewski 1962), 1969–1971 (Klekot 1980), 1979 and 1988 (this study).

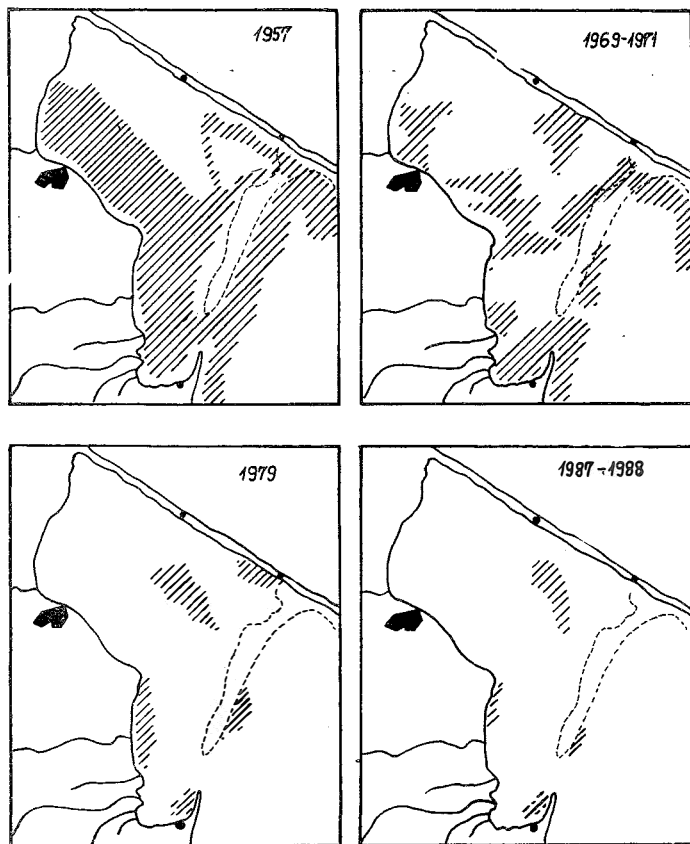


Fig. 5. Changes in distribution of *Zostera marina* L. in the Puck Lagoon, as revealed by comparison of data collected in 1957 (Ciszewski 1962), 1969–1971 (Klekot 1980), 1979, 1987, and 1988 (this study)

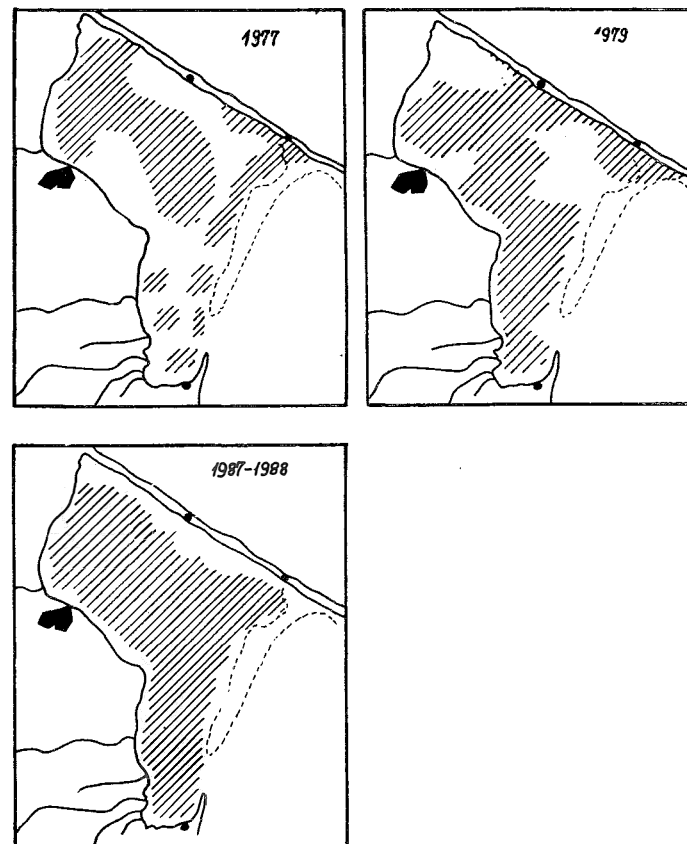


Fig. 6. Changes in distribution of *Pilayella littoralis* Kjellm. and *Ectocarpus* sp. in the Puck Lagoon, as revealed by comparison of data collected in 1977 (Pliński 1982), 1979, 1987 and 1988 (this study).

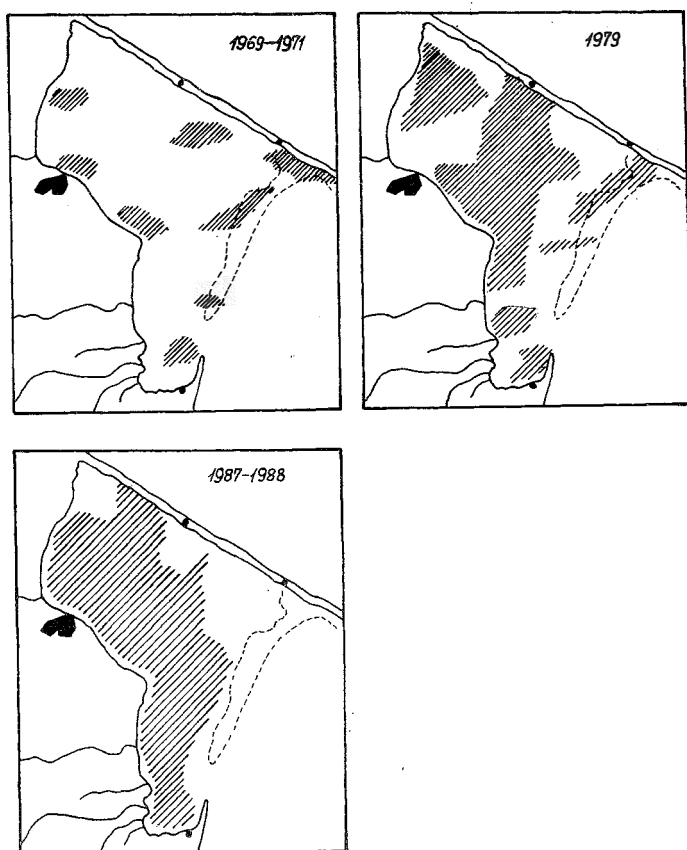


Fig. 7. Changes in distribution of *Zannichellia palustris* L. in the Puck Lagoon, as revealed by comparison of data collected in 1969-1971 (Klekov 1980), 1979, 1987 and 1988 (this study).

past and they are absent at present (Photo 1). The disappearance of the two species is shown in Figs. 3 and 4. The spatial coverage of *Zosteramarina* was also confined in the period between 1957 (Photo 2) and present (Fig. 5). During the last 10 years, *Pilayella littoralis* and *Ectocarpus siliculosus* (Ectocarpaceae) as well as *Zannichellia palustris* (Cormophyta) expanded their spatial coverages to encompass almost the entire area of the Puck Lagoon's bottom (Figs 6 and 7). The three species mentioned replaced *Furcellaria lumbricalis* and *Fucus vesiculosus* which disappeared due to anthropogenic pollution.

At present, the underwater meadows of a large area of the Puck Lagoon consist of the Ectocarpaceae and *Zannichellia palustris*. In August and September, the meadows are distinctly dominated by *Z. palustris* and, to a certain degree, by other Cormophyta species.



Photo 2. Underwater meadows (*Zostera marina*) in 1957 (Photo: P. Ciszewski)

### ACKNOWLEDGEMENTS

Dr P. Ciszewski has kindly made his unique photographs of the underwater meadows, taken in 1957, available to the author, for which he is sincerely thanked.

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