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Histopathology of mussels (*Mytilus edulis* L.) from the Tvärminne area, the Gulf of Finland (Baltic Sea)

Inke Sunila

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Histopathological examinations were performed on eight mussel (*Mytilus edulis* L.) samples from the Tvärminne area, on the southern coast of Finland. Three of the samples were from relatively unpolluted benthic sites and five samples composed a cline from an iron and steel factory to the open sea. Seventy per cent of the animals from the entire study area had an inflammatory reaction. About one-third of these inflammatory reactions were of parasitic origin. Fifty per cent of the animals in the harbour of the factory had gill lesions, where the gill filaments were fused, ciliary interfilamentar junctions were replaced by metaplastic cellular junctions, epithelium was hyperplastic, and there was a chronic inflammatory reaction in the gills. The sample from Lernäs, at a distance of three kilometres from the factory, had a high prevalence of degenerative changes: atrophy of muscle bundles and vacuolation of digestive cells. There was a high prevalence of benign tumours, rhabdomyomas, in the auricles of this sample. One animal with an undifferentiated sarcoma was found near the island of Furuskär. Mussels in all samples exhibited excessive mucous production and had dark granules in the kidney cells. Although the condition of the mussels was poorer in the vicinity of the factory, none of the samples represented healthy mussels from an area without anthropogenic stress.

Inke Sunila, Department of Zoology, Division of Physiology, University of Helsinki, Arkadiankatu 7, SF-00100 Helsinki.

1. Introduction

The International Mussel Watch is a marine monitoring programme which studies pollution problems in estuaries all over the world by using common mussels, *Mytilus* spp., as indicator organisms. Methods of the Mussel Watch include analyses of tissues for bioaccumulation of heavy metals, halogenated hydrocarbons, oil and radionuclide pollution (e.g. Goldberg 1980), as well as the determination of mussel health via physiological tests and histopathological analysis. The rationale for the Mussel Watch monitoring is as follows:

1. Bivalves are cosmopolitan.

2. They are sedentary and thus superior to mobile species as integrators of chemical pollution for a given area.

3. They concentrate many chemicals by factors of 10^2–10^5 compared to seawater. This makes trace constituent measurements easier to accomplish in their tissues than in seawater.

4. Accumulated amounts represent those forms which are biologically available to organisms.

5. The chemicals are accumulated over an extended period, thus representing the sum of environmental insults in the recent history of the ecosystem.

6. In comparison to fish and crustacea, bivalves have a low or undetectable activity of those enzyme systems that metabolize many xenobiotics such as aromatic hydrocarbons and polychlorinated biphenyls.

7. They have many relatively stable local populations extensive enough to be sampled repeatedly.

8. They can survive under polluted conditions that often reduce or eliminate populations of other species.

9. They are commercially valuable seafood species. Thus, measurement of chemical contamination is of interest for public health considerations (Farrington et al. 1983, Simkiss et al. 1982).

Histopathological analysis provides information about the general health of the animals and contami-

nant-specific changes in the tissues. Cyclic changes in the reproductive system and digestive diverticula, as well as the reactions to parasites and micro-organisms, must be taken into account before an attempt is made to correlate histopathological changes with pollution (Yevich & Barszcz 1976).

In the northern Baltic Sea the local populations of mussels have no commercial value. Mussel Watch monitoring has not been applied to the northern Baltic Sea. However, *Mytilus* totally dominates the animal biomass on Baltic hardbottoms (Kautsky 1981). Histopathology of mussels has been studied only once (Sunila 1986a). In order to determine if histopathology of the mussel (*Mytilus edulis*) can aid in monitoring pollution along these coasts, mussels were sampled from eight different stations. Five of the stations represented a cline from the harbour of an iron and steel factory to the open sea to evaluate the effects of the discharge waters on the tissues of the animals. Three samples were collected from areas near the Tvärminne Zoological Station that are considered to be unpolluted, to provide a baseline of tissue conditions with which to compare for pathological purposes.

When histopathological studies are used in a monitoring programme, the observed changes should have an ecological significance, having an adverse or damaging effect on e.g. growth, reproduction or the survival of the individual and the population. In this study, all the histopathological observations, including single cases, are described because of the lack of histopathological data on Baltic mussels. The significance of the observations from the point of monitoring is discussed.

2.Material and methods

2.1. Microscopical techniques

Samples from eight mussel (*Mytilus edulis* L.) populations from the Tvärminne area, on the southern coast of Finland, were taken by a diver. Twenty-five specimens from each sampling location were immediately removed from the shell and immersed in Helly's fixative (Barzcz & Yevich 1975). 8 µm thick paraffin sections were stained with hematoxilyn-eosin. Samples exhibiting pathology that needed further examination were recut and stained using special techniques. The slides from a mussel with a sarcoma were stained with Feulgen Picromethyl Blue (Howard & Smith 1983) and the cases with inflammatory reactions of unknown origin with Twort's Gram method for the detection of bacteria (Yevich et al. 1985).

A photometric analysis was made of the kidneys of the mussels. A microscope with a Leitz-Mikroskope-Photometer MPE was coupled to a stabilized voltage source. There was a gradually regulated diaphraghm with a spectral filter on the base of the microscope. Absorption was read from the scale of a galvanometer (10^{-9} A). By adjusting the diaphraghm the intensity of the light passing through a tissue area with a diameter of 65 µm was measured at a time. The photomultipler supplied an electric current through this area, the intensity of which was proportional to the intensity of light which passed through the tissue. The scale of the galvanometer was adjusted so that inactive kidneys (with no granules in the kidney cells) had a light absorption of 100 % and kidneys with dark granules in their cells showed a percentage of this. Ten cells from the kidney tubule epithelium were measured from ten specimens from each sampling site.

2.2. Sampling locations

Three samples were collected in September from relatively unpolluted bottoms ranging from the vicinity of the bay Pohjanpitäjänlahti to the open sea (Fig. 1). The first sampling station was Vitsand, which is the last coherent mussel field near Pohjanpitäjänlahti. There the low salinity of the bay imposes limits on the distribution of *Mytilus*. At the sampling station the salinity is 5–6 ‰ at the bottom and 1–4 ‰ in the surface layers (Halme 1944). The second sampling station was Sundholmen, near the Tvärminne Zoological Station, and the third Flakaskär. Five samples composed a cline from an iron and steel factory to the open sea within a distance of 6 km. The first sample was collected from the entrance of the harbour of the factory, the second from Syndalsnäs at a distance of 1.5 km, the third from Lernäs at a distance of 3.0 km, the fourth from Tvärminne at a distance of 4.5 km and the fifth from Furuskär at a distance of 6 km from the factory (depth 9–14 m). According to Niemi (1973) Vitsand is situated in the coastal zone and the other sampling stations in the outer archipelago zone.

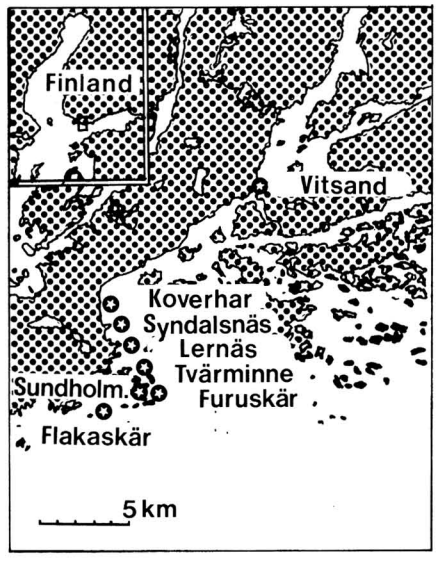

Fig. 1. A map of the study area.

Fig. 2. A hermaphrodite with mixed follicles, both sperm and ova ripening from the germinal epithelium in the same follicles. Scale bar 250 μm.

Table 1. Frequency (individuals) of different sex and gametogenesis stages in *Mytilus edulis*.

Sampling location	N	Male	Female	Herma-phrodite	Indeterminate	Castrated	Resorption	Cleaning process	Gonad index
Vitsand	25	0.52	0.36	–	0.08	0.04	0.08	0.20	2.44
Flakaskär	26	0.35	0.12	0.04	0.46	0.04	–	0.04	0.81
Sundholmen	24	0.25	0.42	–	0.29	0.04	0.04	0.21	1.50
Furuskär	26	0.42	0.42	–	0.12	0.04	0.08	–	2.19
Tvärminne	27	0.52	0.44	–	0.04	–	0.22	0.04	2.22
Lernäs	25	0.40	0.44	0.04	0.12	–	0.12	0.04	1.76
Syndalsnäs	25	0.40	0.56	–	–	0.04	0.16	0.08	2.52
Koverhar	27	0.41	0.56	–	0.04	–	0.08	0.04	1.67

3. Results and discussion

3.1. Sex and gametogenesis

Sex and gametogenesis of the samples is summarized in Table 1. The sex ratio was 1:1 and two specimens of 205 individuals studied were hermaphrodites. One hermaphrodite had separate male and female follicles but the other represented a rare case of mixed follicles, with both sperm and ova ripening from the germinal epithelium in the same follicles (Fig. 2).

The developmental and spawning stages of the gonads were classified according to Seed (1969) and a gonad index calculated. Gonad index varies from zero, when no sexual activity is noted, to five, when all the individuals are mature. "Indeterminate" refers to stage 0, when there are no gametes in the follicles and the sex of the individual cannot be determined. It is a normal stage of the reproduction cycle. In castrated specimens no gametes are ripening and this represents a pathological stage. Castration in these samples was due to trematode-infection (from Flakaskär and Sundholmen), sarcoma (Furuskär), or fibrosis (Syndalsnäs), or was of unknown origin (Vitsand). Resorption refers to the stage in female follicles, when the ova are resorbed at the end of the breeding cycle or under stress (Bayne et al. 1978). Resorption was common in the sample from Tvärminne (0.22), which was unusually high at this stage of the breeding cycle, in June just before spawning. The cleaning process occurs at the end of the breeding cycle and is a normal part of it. Remnants of sperm and ova are phagocytosed and transferred via diapedesis through epithelia. The process can be so vigorous that it resembles an inflammatory

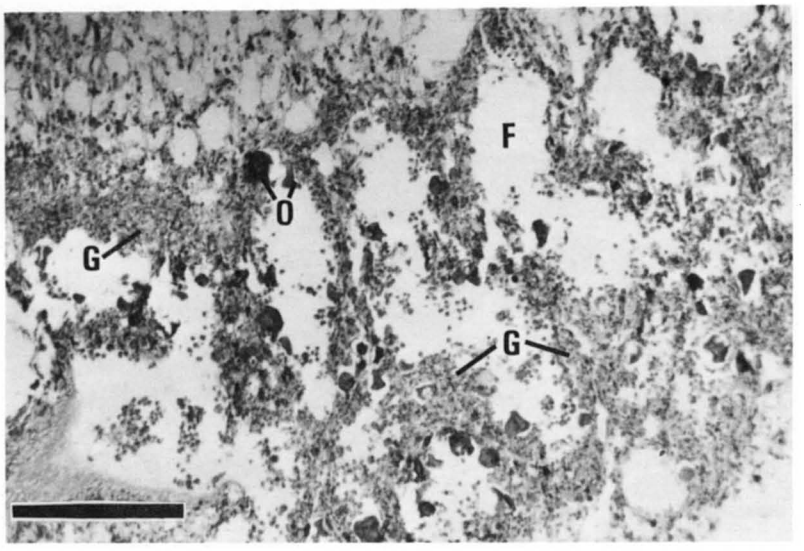

Fig. 3. Cleaning process in the follicles (F) in the end of spawning. Remnants of ova (O) are phagocytosed by granular hemocytes (G) and transferred through epithelia to the exterior. Scale bar 250 µm.

Table 2. Frequency (individuals) of different inflammatory responses in *Mytilus edulis*.

Sampling location	Total	Acute						Chronic			
		total	infiltration	phagocytosis	hemocytic encapsul.	diapedesis	exudation	total	hyaline hemocyte infiltration focal	hyaline hemocyte infiltration systemic	collageneous encapsul.
Vitsand	0.76	0.52	0.32	0.04	–	0.40	–	0.20	0.08	0.04	0.08
Flakaskär	0.65	0.65	0.27	–	0.08	0.50	0.04	0.08	–	–	0.08
Sundholmen	0.67	0.63	0.08	–	–	0.54	–	–	–	–	–
Furuskär	0.67	0.50	–	–	0.04	0.38	–	0.19	0.12	0.04	–
Tvärminne	0.63	0.56	0.44	0.04	0.08	0.22	–	–	–	–	–
Lernäs	0.96	0.88	0.16	0.04	0.04	0.76	0.04	0.24	0.16	0.12	0.04
Syndalsnäs	0.64	0.40	0.32	–	–	0.12	–	0.20	0.16	–	0.04
Koverhar	0.80	0.44	0.26	0.04	–	0.19	–	0.15	0.08	–	0.04

reaction (Fig. 3). Thus the stage of gametogenesis must be kept in mind when studying the samples. The cleaning process was common in the samples from Vitsand (0.20) and Sundholmen (0.21) that were collected in September and represented individuals at the end of their spawning cycle.

3.2. Inflammatory responses

Inflammatory responses in the study area are summarized in Table 2. There were specimens with acute and chronic inflammatory reactions. Types of acute inflammatory reactions were:

Acute infiltration

This condition was usually due to parasitic infestations. Infiltration of hemocytes occurred mostly in the digestive diverticula (67 %), rarely in the mantle, gills, plicate membranes or palps. Acute infiltration was multifocal in 20 % of the specimens.

Phagocytosis

Phagocytosis always occurred in the follicles. Phagocytosis in the follicles can be a controlled event, as with the phagocytosis of residual gametes at the end of the breeding period. It can also be a pathological event, as with the extensive phagocytosis of sperm after heavy metal stress (Sunila 1984). In this study, only pathological phagocytosis, resulting in cytolysed sperm in still developing follicles, was taken into account.

Hemocytic encapsulation

Hemocytic encapsulation was due to parasitic infestation in each case. In four animals it occurred in the digestive diverticula, but in the two cases from Tvärminne this condition was found in the foot.

Table 3. Frequency (individuals) of different degenerative changes in *Mytilus edulis*.

Sampling location	Atrophy muscle bundles	Atrophy digestive tubules	Ceroidosis	Erosion	Sloughage	Vacuolation digestive	Vacuolation byssus gland	Metaplasia digestive tubules	Metaplasia intestine epithel.	Dilatation follicles	Dilatation plicate membr.	Dilatation kidney tubules	Kidney concretions
Vitsand	0.08	–	0.04	–	–	–	–	–	–	0.08	0.04	–	–
Flakaskär	–	0.04	–	–	–	–	–	–	–	–	0.04	–	–
Sundholmen	–	–	–	–	–	–	–	0.08	–	0.08	–	–	–
Furuskär	–	–	–	–	–	–	0.04	0.08	–	–	0.04	–	–
Tvärminne	0.04	–	–	–	–	–	0.08	–	–	–	–	–	–
Lernäs	0.64	–	–	–	–	0.36	–	0.08	–	0.16	0.16	–	0.12
Syndalsnäs	0.32	–	–	0.04	–	–	–	–	–	0.08	–	–	0.12
Koverhar	0.15	0.08	0.04	0.04	0.04	0.08	–	0.11	0.04	0.04	0.04	0.04	0.08

Diapedesis

Diapedesis refers to the migration of hemocytes through the epithelia. It is a normal phenomenon in the cleaning process at the end of the breeding cycle, but is also activated in many pathological conditions. In parasitic infestations the remnants of the parasites which are destroyed by the host response are transferred to the exterior via diapedesis. It is activated also under pollution stress, when e.g. heavy metals are transferred to the exterior in hemocytes in tertiary lysosomes (George 1983).

Types of chronic inflammatory responses were:

Focal hyaline hemocyte infiltration

This condition occurred in association with kidney concretions at the three sampling stations near the factory (Koverhar, Syndalsnäs, Lernäs). The origin of the other cases remained generally unresolved. Hyaline hemocyte foci were found in digestive diverticula, gills, palps, mantle or follicles. In one specimen from Furuskär a multifocal hyaline cell response was accompanied by an infection of Gram-positive bacteria.

Systemic hyaline hemocyte infiltration

In these cases, remnants of destroyed Metazoan parasites were found in the tissues of the mussels.

Collagenous encapsulation

Collagen deposition in the defense mechanisms of mussels has not been verified, but this name is used here for capsule formation by the proliferation of fibrocytes. At Flakaskär there were two Metazoan parasites in the pericardium of the mussel within a capsule, probably Echinostromatidea. At Koverhar there was one animal with an encapsulated Arthropoda in the digestive diverticula.

The average total probability of finding a specimen with an inflammatory reaction in the study area was 70 %. On the average, 34 % of these cases were due to parasitic origin (Vitsand 42 %, Flakaskär 60 %, Sundholmen 12 %, Furuskär 40 %, Tvärminne 52 %, Lernäs 21 %, Syndalsnäs 23 % and Koverhar 19 %). An average of 24 % of animals (63 % at Koverhar) with inflammatory responses had gill lesions. Most of the other cases — lacking parasites or gill lesions, but with an inflammatory reaction — showed diapedesis. This might be due to heavy metal stress.

3.3. Degenerative changes

Degenerative changes in the samples are summarized in Table 3.

Atrophy

Atrophy of muscle bundles was common in the samples from Lernäs (0.64), and also in the samples from Syndalsnäs (0.32) and Koverhar (0.15). The atrophic muscle cells were round and had a clear space around them (Fig. 4). This consequential degradation of visceral components is associated with starvation. Atrophy of digestive tubules was observed in one animal from Flakaskär and two animals from Koverhar.

Ceroidosis

Accumulation of lipofuchsin granules due to lipid peroxidation was observed in one animal from Vitsand and one from Koverhar.

Erosion

Erosion occurred in the cytoplasm of digestive cells in one animal from Koverhar and in the epithelium of kidney tubules in one animal from Syndalsnäs.

Sloughing

Release of the cells lining the digestive tubules was observed in one animal from Koverhar. The

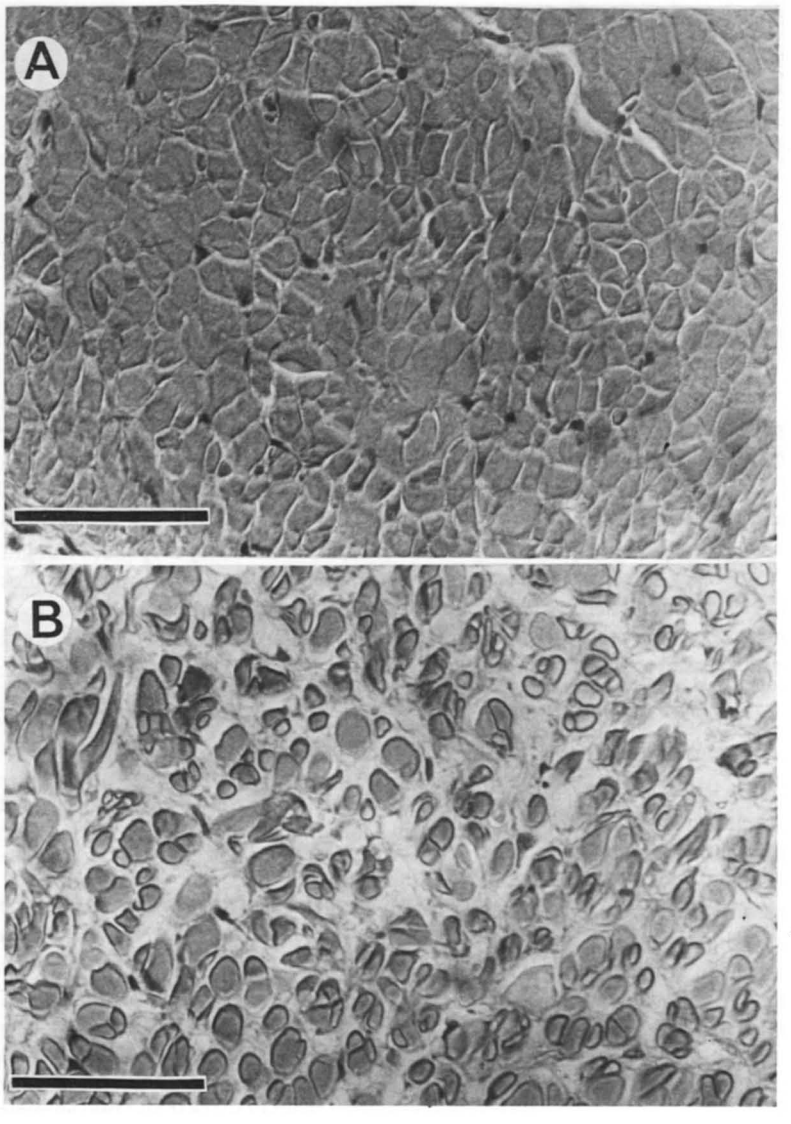

Fig. 4. — A. Muscle bundles. Control. — B. Atrophy of muscle bundles with round muscle cells with a clear space around them. Scale bars 50 µm.

cells were necrotic and filled the lumens of the tubules. This condition was very common in a sample collected near the waste outfall tube of a titanium dioxide plant in the Bothnian Bay (Sunila 1986a).

Vacuolation

Vacuolation of digestive cells was common in the sample from Lernäs (0.36). Vacuoles appeared at the apical end of the cells and were associated with starvation. Vacuolation of the septal area of the byssus gland (Fig. 5) was found in two animals from Tvärminne and one from Furuskär.

Cyst

A cyst was found in the kidney of one animal from Tvärminne. The cyst wall was composed of two cell layers with a lumen between them. There was an inflammatory reaction surrounding it.

Metaplasia

Metaplasia of digestive tubules was observed in several specimens. Normally, the tubules show great variability according to the feeding rhythm, ranging from thick-walled tubules with a narrow lumen to wide thin-walled tubules (Langton 1975). In the metaplastic tubules the epithelium was squamous and

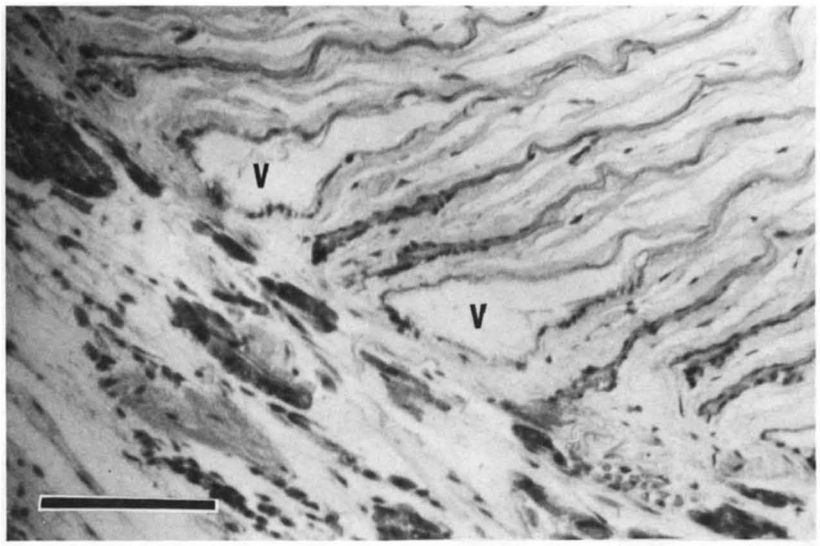

Fig. 5. Vacuolation (V) of the septal area of the byssus gland. Scale bar 100 µm.

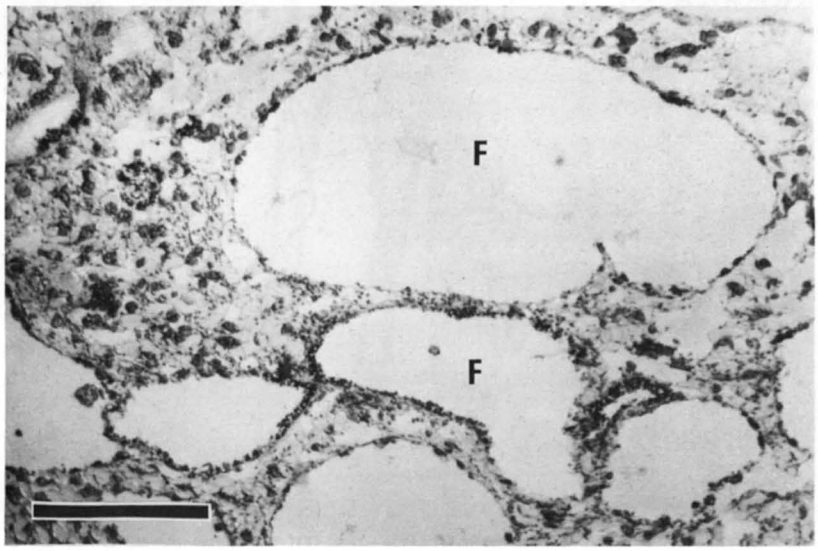

Fig. 6. Dilatation of the reproductive follicles (F). Scale bar 250 µm.

had no striated border against the lumen. In one animal from Koverhar there was a metaplastic cuboidal epithelium in the intestine.

Dilatation

Of follicles:

At the end of spawning, after the release of gametes, follicles and genital canals disappear and are replaced by connective tissue cells. This did not occur in all the animals and the follicles remained dilated after spawning (Fig. 6). There was a prevalence of 0.16 of dilated follicles in the Lernäs sample.

Of plicate membranes:

The plicate membranes were dilated with a prevalence of 0.16 in the Lernäs sample (Fig. 7). The function of the plicate organ is not known.

Of kidney:

The primary tubules of the kidney of one animal from Koverhar were dilated.

Kidney concretions

Concretions were found in the kidneys from Koverhar (0.20), Syndalsnäs and Lernäs. Concretions are formed under e.g. heavy metal stress (Rheinberger et al. 1979).

Atrophy of muscle bundles and vacuolation of digestive cells was typical in the animals from

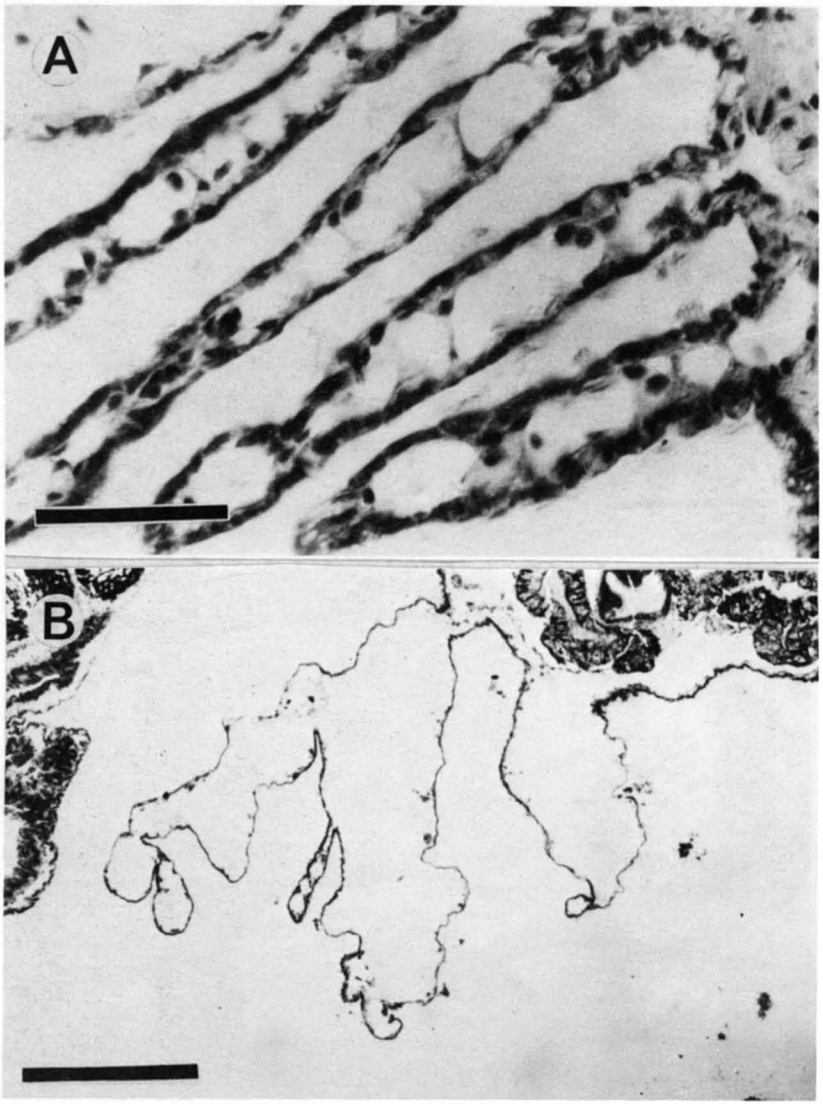

Fig. 7. — A. Plicate membranes. Control. Scale bar 50 µm. — B. Dilatation of the plicate membranes. Scale bar 250 µm.

Lernäs. Other degenerative changes occurred at low prevalence. However, the sample from Koverhar showed a wide variety of these lesions: 48 % of these animals had some kind of degenerative change.

3.4. Physiological factors

Mucous production and photometric measurements of the kidneys are represented in Table 4. Mucous production was observed in the ciliary epithelium of the gills. It was common in all the samples. In Koverhar its frequency was 0.85. Mucous production in mussels is activated under pollution stress (e.g. Scott & Major 1972, Engel & Fowler 1979, George & Pirie 1980). Kidney cells of the mussels from Koverhar and Flakaskär were very dark. The Vitsand sample had clean kidneys.

Other changes

There was a necrotic area in the digestive diverticula of one animal from Lernäs. It was of hyaline type and surrounded by a fibrocytic and hemocytic capsule. There was hemorrhage into the stomach in one animal from Tvärminne and into the digestive tubules in one animal from Lernäs of unknown origin. In two animals, one from Vitsand and the other one from Syndalsnäs, there were abnormal

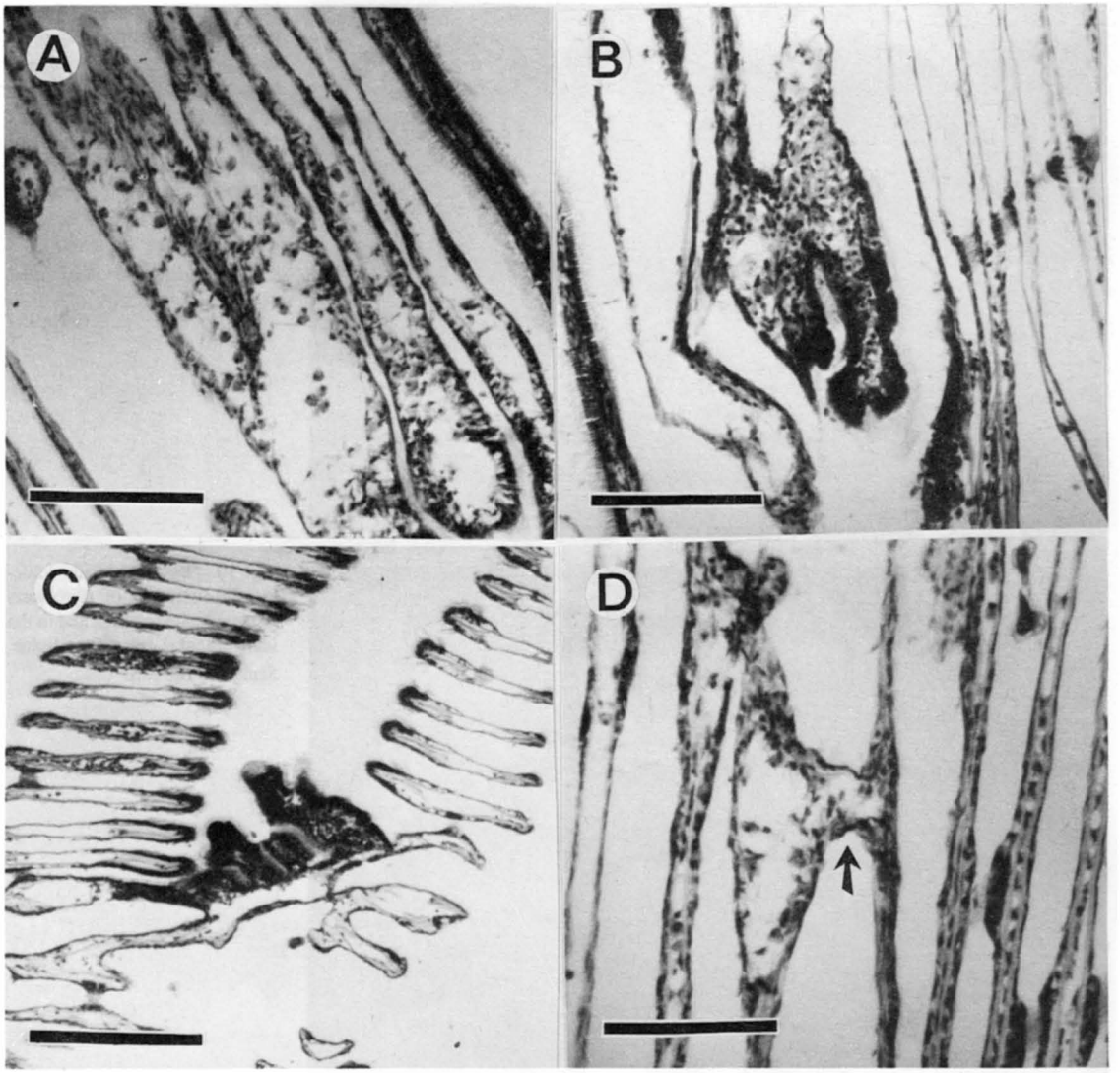

Fig. 8. Gill lesions. — A. Fusion of the gill filaments. Scale bar 100 µm. — B. A metaplastic interfilamentar junction with basophilic, hyperplastic epithelia. Scale bar 100 µm. — C. Metaplastic, basophilic epithelia in the middle of the gill filaments. Scale bar 250 µm. — D. A metaplastic, cellular interfilamentar junction (arrow). Scale bar 100 µm.

male follicles. The release of sperm to the sea water had not occurred and the follicles were filled with ripe sperm without its normal organisation.

3.5. Proliferative changes and neoplasia

These disorders are summarized in Table 5.

Gill lesions

The gill lesions (Fig. 8) were typical to the specimens collected from the harbour of the iron and steel factory and rare at other sampling stations. No bacteria could be detected by Gram-stain in the tissues of the animals with this condition. There were fusions of the gill filaments (Fig. 8A) and part of the ciliary interfilamentar junctions were replaced by metaplastic cellular connections (Fig. 8B). Epithelia of the filaments beside the metaplastic sites were basophilic and hyperplastic (Fig. 8C and 8D). There was a chronic inflammatory reaction inside the gill filaments. Filaments near the food groove were swollen. Copper-induced fusions in the gills of *Mytilus* are described by Sunila (1986b).

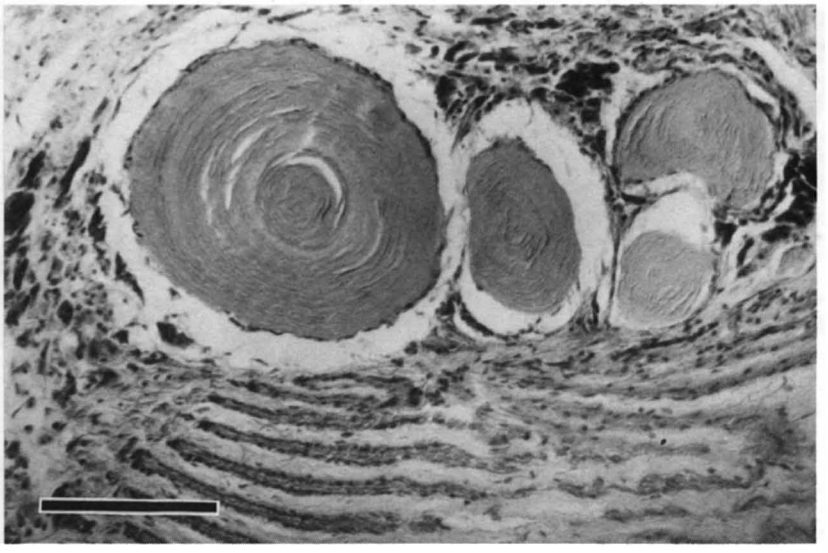

Fig. 9. Abnormal thread formation. Byssus threads are formed inside the septal area of the byssus gland. Scale bar 100 µm.

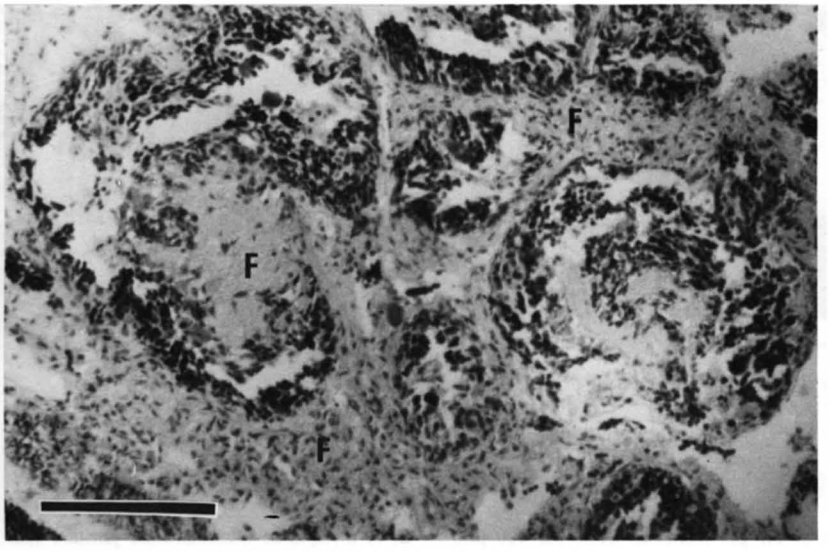

Fig. 10. Fibrosis in male follicles. Proliferation of fibroblasts (F) inside the follicles and in the interfollicular connective tissue. Scale bar 100 µm.

Table 4. Physiological condition of gills and kidneys in *Mytilus edulis*. Mucous production in gills: frequency of individuals. Kidney photometry: proportion of light absorption, inactive state = 100.

Sampling location	Mucous production	Kidney photometry
Vitsand	0.52	68.62
Flakaskär	0.42	5.37
Sundholmen	0.50	15.47
Furuskär	0.42	10.92
Tvärminne	0.66	15.86
Lernäs	0.64	31.58
Syndalsnäs	0.72	40.62
Koverhar	0.85	4.97

Table 5. Frequency (individuals) of proliferative changes and neoplasia in *Mytilus edulis*.

Sampling location	Gill lesions	Abnormal thread formation	Fibrosis	Tumors rhabdomyoma	Tumors sarcoma
Vitsand	0.16	0.04	0.04	0.04	–
Flakaskär	0.04	0.04	–	–	–
Sundholmen	0.13	0.04	–	–	–
Furuskär	0.16	0.08	–	–	0.04
Tvärminne	0.22	0.04	–	–	–
Lernäs	0.13	–	0.08	0.20	–
Syndalsnäs	0.08	–	0.08	–	–
Koverhar	0.50	–	0.04	–	–

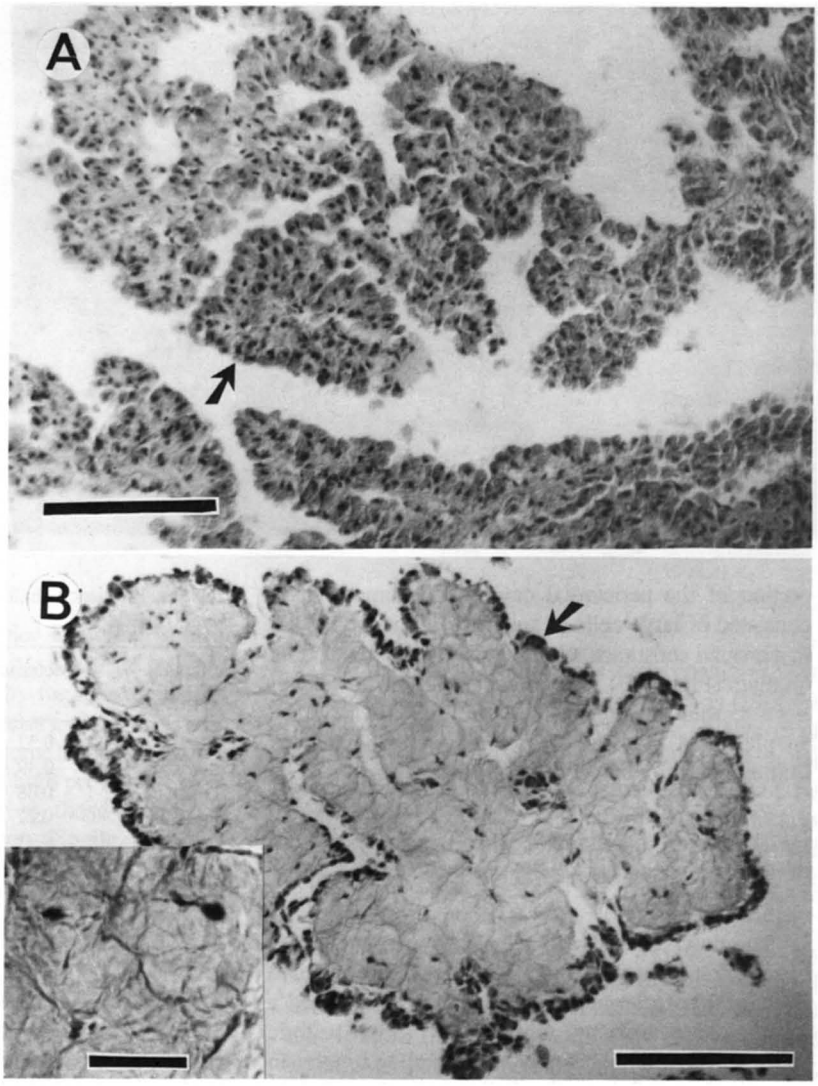

Fig. 11. — A. An auricle with pericardial gland cells (arrow). Control. Scale bar 100 µm. — B. Rhabdomyoma of the heart. The tumour mass consists of spider cells embedded in ground substance and is bordered by pericardial gland cells (arrow). Scale bar 100 µm. Insert: Spider cell formation in the tumour mass. Scale bar 25 µm.

Abnormal thread formation

The collagen fibres form parallel structures in the septal area of the byssus gland (Pujol et al. 1972). In some animals the thread was formed inside the byssus gland and not in the foot groove in contact with sea water, as it usually is (Fig.9). The threads inside the gland were of different sizes, but usually much larger in diameter than normal byssus threads.

Fibrosis

Fibrosis refers to proliferation of fibroblasts in tissues where they are normally present. Fibrosis occurred in the follicles so that the entire follicle was often filled with fibrocytes. They proliferated also in the connective tissue between germinal canals and follicles (Fig. 10).

Tumours

Rhabdomyoma

There was a prevalence of 0.20 of this tumour in the Lernäs sample (Fig. 11). The tumours developed from the auricle in the pericardial cavity. Normal auricles of *Mytilus* are situated on both sides of the ventricle. The intestine passes through the ventricle. Pericardial gland cells are situated on the surfaces of the auricles (Fig. 11A). Auricles with a rhabdomyoma were enlarged and had invaded a large

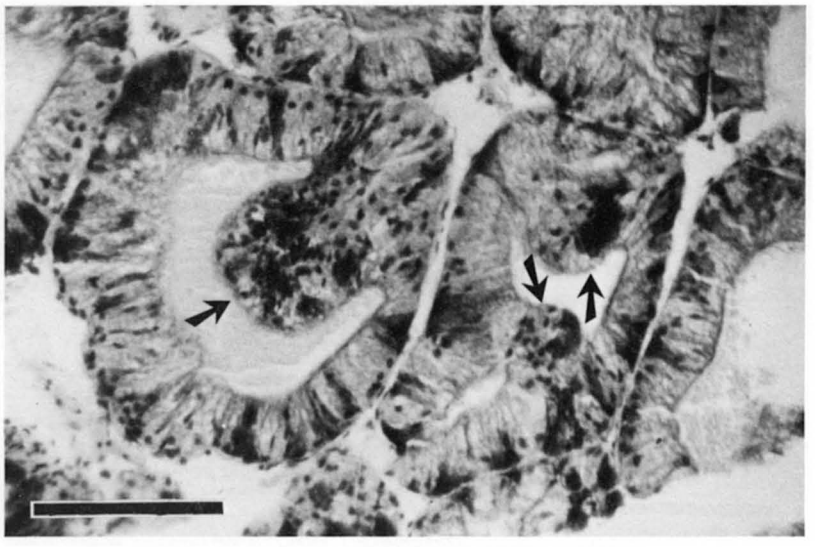

Fig. 12. Polypoid epithelia (arrows) in the digestive tubules. Scale bar 50 µm.

portion of the pericardial cavity. The tumour mass consisted of large cells of spider cell type embedded in a ground substance with the pericardial gland cells on them (Fig. 11 B). These benign tumours originate from cardial muscles; they are not invasive or anaplastic. All the rhabdomyomas were found from Lernäs, except one case from Vitsand.

Polyps

There was one animal with polypoid epithelium of digestive tubules at Koverhar (Fig.12).

Sarcoma

The only case of malignant neoplasm was found at Furuskär. The tissues of the animal were invaded by large hyperchromatic, anaplastic cells that had a high nuclei/cytoplasm ratio (Fig. 13). Some mitotic figures were found. There were refractile vacuoles in the cytoplasm of the cells. Cells were often slightly elongate. On the basis of the morphological characteristics of these cells and their distribution in the tissues this condition was classified as an undifferentiated sarcoma.

3.6. Parasites and bacteria

The occurrence of parasites and bacteria is summarized in Table 6. On the average 24 % of the specimens in the study area were invaded by Metazoan parasites. They were usually Trematodes and Nematodes in the digestive diverticula and the mantle. The Metazoan parasites evoked a strong inflammatory reaction and were usually almost totally destroyed by the host response.

Table 6. Frequency (individuals) of parasites and bacteria in *Mytilus edulis*.

Sampling location	Metazoa	Protozoa	Gram-positive bacteria
Vitsand	0.32	0.36	–
Flakaskär	0.39	0.58	–
Sundholmen	0.08	0.55	–
Furuskär	0.27	0.12	0.04
Tvärminne	0.33	0.19	–
Lernäs	0.20	0.04	0.04
Syndalsnäs	0.24	0.24	0.04
Koverhar	0.15	0.08	–

There were ciliates on the surfaces of the gills of the mussels. They seemed to be commensals and evoked no host response. They were very common in the samples from Flakaskär and Sundholmen. In Vitsand there were intracellular parasites in the digestive cells of one animal, probably Sporozoan.There was an inflammation induced by Gram-positive cocci in three animals. Most of the bacteria were found in the epithelium of the intestine. All information about the species of parasites in Baltic mussels and their occurrence with reference to pollution stress would be of great value.

3.7.Discussion of the sampling stations

Mussels collected from each of the sampling stations exhibited pathological changes. There was a high occurrence of mucous production and inflam-

Fig. 13. Undifferentiated sarcoma. The tissues are invaded by large, hyperchromatic sarcoma cells. Scale bar 250 µm. Insert: Sarcoma cells. They have large nuclei and refractile vacuoles in the cytoplasm. Scale bar 10 µm.

matory reaction in each sample. The cline from the iron and steel factory did not have a clean reference population at the other end, by the open sea. However, in the vicinity of the factory there were many more pathological changes, some of which may be pollution related. There was a high prevalence of gill lesions, which were similar to those induced by copper-exposure in the laboratory (Sunila, 1986b).

Vitsand

The sample was in moderate condition. The kidneys were appreciably cleaner than in other samples; they were pale and there was no excess hemocyte excretion through the epithelia. No direct effects of environmental pollutants can be associated with the changes in this sample.

Flakaskär

The sample was in moderate condition. The kidneys were nearly black and received a value of 5.3 in the densitometric studies. The highest occurrence of commensale ciliates was observed in this sample. This area is influenced by boat and ship traffic.

Sundholmen

The sample was in moderate condition.

Furuskär

The sample was in moderate condition. The only case of cancer was observed in this sample.

Tvärminne

The sample was in moderate condition.

Lernäs

The sample was in a very poor condition. The occurrence of inflammatory reactions was 0.96, the highest in the study area. There was dilatation of follicles and plicate membranes. Muscle bundles were atrophic (0.64) and digestive cells vacuolated (0.36).There was a frequency of 0.20 of benign neoplasms, rhabdomyomas, in this sample. The etiology of this condition is unknown.

Syndalsnäs

This sample was in moderate to poor condition. Atrophy of muscle bundles occurred in 0.32. The sample was clearly in a better condition than the sample from Lernäs. The sampling station is located 1.5 kilometres from the Koverhar factory. However, the sampling station seems to be protected from the discharge waters. There is a sand bank, which continues from the mainland to the island of Syndalsholmen and on which the sample was collected from a depth of 9 metres. It is possible that this forms a barrier which keeps the mussels from being washed with discharge waters.

Koverhar

This sample was in a very poor condition. The frequency of inflammatory reaction was 0.80 and of mucous production 0.85. Kidneys were very dark (4.97). There was a variety of degenerative changes in this sample. Typical to this sample was a high occurrence of the gill lesions (0.50).

The distribution of the discharge waters of the

factory by using different biological indicators has been studied by Luotamo & Luotamo (1979). A new cleaning system for the blast furnace gas was adopted in 1982, after which most of the heavy metals (e.g. 80 % of zinc) were removed from the discharge waters. As the mussels in this study were sampled in 1985 and their age was on the average 4.7 years (size 2.5 cm ± 0.8 cm), the events before this reform enter into their life histories. Hietanen (1986) measured the accumulation of zinc from the same sampling stations as in this study (Koverhar 358, Syndalsnäs 169, Lernäs 239, Tvärminne 205 and Furuskär 184 µg Zn/g DW). In her results there was the same trend as in this study: accumulation was low in Syndalsnäs. The increase of shell deformities when approaching Koverhar as described by Lindström (1986) was not observed in these samples.

The histopathological changes seen in the present study do not resemble the changes observed outside a titanium dioxide plant in the Bothnian Bay (Sunila 1986a). These changes included abnormal spawning and sloughing of epithelia in digestive tubules. A physiological response, the dark kidneys, did resemble the samples of this study.

Part of the histopathological changes in this study are of value for monitoring purposes. The gill lesions, which are most probably associated with heavy metal stress, affect gas exchange and food transport. Rhabdomyomas affect movement of the heart, interfering with circulation, and excretion. Fresh evidence on the auricles as a site of ultrafiltration in bivalves was published by Meyhöfer et al. (1986). The occurrence of sarcomas, (in this study a single case), might indicate carcinogens in seawater. The occurrence of neoplasia in bivalve molluscs has been reported e.g. by Frierman 1976, Yevich & Barszcz 1977, Brown et al. 1979, Cooper et al. 1982 and Green & Alderman 1983. Photometric measurement of the kidneys as a quick method might also be of value in large scale monitoring.

Results from the histopathological examination of the U.S. Mussel Watch are reported by Yevich & Barszcz (1983). Future studies will reveal whether the sampling area of this study represented an exception or whether the mussels on our coasts always exhibit a lot of histopathological changes — they live here under stress at the limits of their distribution, under a low salinity (7 ‰) and high pollutant levels.

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