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CONTRIBUTIONS TO THE KNOWLEDGE OF THE FOULING ON THE ROMANIAN MARITIME SHIPS

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ABSTRACT

The authors conducted a qualitative and quantitative analysis of the fouling on the Romanian ships harboured in Constantza - Black Sea, on the basis of 152 samples collected from the keel of 16 ships having operated in different geographical areas.
The results obtained are correlated with the utilization rate of the ships and with the main geographical areas travelled by them (the Black Sea - Romanian shore, the Black Sea - the Mediterranean and the Black Sea - the Mediterranean - other seas).

It is well known that on a world scale, the knowledge and the fight against marine fouling represent a problem of high economical interest, and, as such, the studies carried out in this respect have been enhanced these last few years.

As against other seas, the study of the fouling in the Black Sea shows however, a certain lagging, some investigations have been carried out particularly in the Soviet Union.

In Romania, except for a few studies concerning the efficiency of some antivegetative paints, conducted by a team, under the leadership of IOAN PITIS, no other attempts to the knowledge of fouling have been made.

Thus, to combat the marine fouling, an ecological study of epibiotic organisms on the ships keel was necessary. In the following we give the first results obtained.

METHODS

Just after docking, general observations on the ships keel were make and the lay-out of the epibiosis has been noted (Table 1).

Depending on the above, samples were collected by scraping on surfaces of 400 cm^2, by means of a collecting device of our own make, a box with a bag and a scraper at the end. As a rule, we took several samples from an area of the keel uniformly covered with organisms, so that from the 16 ships studied, 152 samples from 61 areas have been processed (Table 1).

The samples were processed in the laboratory, according to the usual studying methods of the benthos, while the results were related to 1 m^2. Biomasses represent the wet weight of organisms.

In the discussion of results we bear in mind the utilization rate of each ship (at sea, on berth) as well as the geographical areas visited (Table 2).

As in literature the terminology concerning the fouling is not uniform we deemed as necessary to use in the discussion of resultes the following terms:

- total fouling (marked with TF) - total weight of epibiosis as related to 1 m^2; TF includes live epibiontic organisms (animal and vegetal), as well as dead calcareous formations (shells of Balanus, tubes of worms), vegetal and animal detritus, sediments, a.s.o.;

- live fouling (LF) - total amount of live organisms, consisting of animal fouling (AF) and vegetal fouling (VF);

- average index of daily deposition of fouling (IF) - result of the ratio between the fouling amount expressed in g/m^2 and the number of days in which the ship was operating (or in a certain situation: at sea, on berth, fresh water, sea water). We would mention that this index has only a guiding value.

Table 1

Ships studied and samples collected for the study of fouling

No.	Name of ship	TDw	Date of sampling	No. of areas analyzed on the ship	Samples collected	Fouling	The remotest area of sailing
	A. Ships operating in the Black Sea basin						
1.	ADAMCLISI	319	20. III. 1973	9	12	non uniform	
2.	MAREA NEAGRA	3,840	05. V. 1973	1	3	uniform	
3.	RAZELM	1,320	22. VI. 1973	3	8	non uniform	
4.	DELTA	340	29. VI. 1973	2	8	non uniform	
5.	TITAN	400	26. VII. 1973	3	3	non uniform	
6.	ARIESUL	97	26. VII. 1973	1	2	uniform	
	B. Ships operating in the Black Sea and the Mediterranean						
7.	MIDIA	580	31. III. 1973	5	5	non uniform	
8.	CARANSEBES	2,520	31. VIII. 1973	4	15	non uniform	
9.	VATRA DORNEI	2,550	31. VIII. 1973	4	8	non uniform	
	C. Ships operating in the Black Sea, the Mediterranean and other seas and oceans						
10.	MAMAIA	8,263	12. IV. 1973	5	12	non uniform	Atlantic
11.	OLTENIA	44,480	13. IV. 1973	3	6	non uniform	Pacific
12.	BRAD	4,795	13. VI. 1973	3	14	non uniform	Atlantic
13.	DOLJ	10,100	22. VI. 1973	2	5	non uniform	Pacific
14.	SINAIA	20,345	29. VI. 1973	5	20	non uniform	Pacific
15.	VRANCEA	17,359	07. VII. 1973	7	14	non uniform	Indian
16.	SUCEAVA	6,360	31. VIII. 1973	4	17	non uniform	Atlantic

Table 2

Data concerning the utilization rate of the ships studied: no. of days when the ship was operational, between two dockings (B. berthed; S-at Sea) and the areas crossed

No.	Name of ships	No. of days between 2 dockings	% of total, no. of days between 2 dockings							% activity days		% activity days		
			DANUBE		BLACK SEA		OTHER SEAS							
			S	M	S	M	S	S	Estuaries M	S	M	Fresh-waters	Black Sea	Other seas
	A. Ships operating on the Black Sea													
1.	ADAMCLISI	232	-	-	39	61	-	-	-	39	61	-	100	-
2.	MAREA NEAGRA	1,190	23	56	6	15	-	-	-	29	71	79	21	-
3.	RAZELM	24	-	-	100	-	-	-	-	100	-	-	100	-
4.	DELTA	547	50	25	15	10	-	-	-	65	35	75	25	-
5.	TITAN	603	37	4	54	5	-	-	-	91	9	41	59	-
6.	ARIESUL	826	-	-	92	8	-	-	-	92	8	-	100	-
	B. Ships operating on the Black Sea and the Mediterranean													
7.	MIDIA	316	6	2	24	7	-	20	41	50	50	8	31	61
8.	CARANSEBES	619	8	1	35	4	-	29	23	72	28	9	39	52
9.	VATRA DORNEI	467	-	-	56	3	-	4	37	60	40	-	59	41
	C. Ships operating on the Black Sea and the Mediterranean and other seas and oceans													
10.	MAMAIA	838	7	1	29	2	10	18	33	64	36	18	31	51
11.	OLTENIA	421	-	-	13	2	1	13	71	27	73	1	15	84
12.	BRAD	622	4	1	16	2	16	16	45	52	48	21	18	61
13.	DOLJ	373	6	1	21	1	13	20	38	60	40	20	22	58
14.	SINAIA	770	-	-	26	1	14	15	44	55	45	14	27	59
15.	VRANCEA	463	-	-	38	1	6	21	34	65	35	6	39	55
16.	SUCEAVA	764	15	1	24	3	12	7	38	58	42	28	27	45

Qualitative and quantitative composition of the fouling on Romanian ships, depending on the main frequented areas

The analysis of the qualitative composition of the fouling on the 16 Romanian ships having sailed in different geographical regions, disclosed the following:

- 36 types of organisms have identified in the composition of the fouling; most of the "macro" formes have been determined up to species, whereas the remaining, by groups (table nr. 3);

- the highest frequency (100% - hence, they occur on all 16 ships studied) was found in the group of Copepoda crustaceans and Nematoda worms; these meiobenthic species, even though not typically epibiotic organisms constantly occur on all ships, irrespective of the geographical areas where they sailed. Copepoda and Nematoda settle in the fouling only after the typically epibiotic organisms (Balanus, incrusting Polychaetae, Bivalves, etc.) are well developed on the keel, forming a thick crust, with numerous anfractuosities, voids, excavations, etc. where sediments are accumulated;

- on all ships, a high enough frequency (50-100%) was found in: Balanus improvisus, Polychaeta worms, the Bivalve Mytilus galloprovincialis, the veliconches of Bivalves and Gastropods. Except for some Polychaetae worms - sedimentophile forms - all organisms mentioned are sessile, basic, permanent constituents of the fouling;

- a lower frequency (under 50%) was found in: Tanais cavolini, Idotea baltica, the worms belonging to the Turbellaria group (with their cocoons) and Oligochaetae, the Bivalve Petricola lithophaga, the Opistobranchia Gastropod Embletonia pulchra.

Most of these organisms are vagile species and settle on the fouling only after the epibiotic system is fully developed;

- a series of organisms show a very low frequency and occur on the ships in close relation with the geographical areas sailed by them; thus, Chtamalus stellatus, Lepadidae the incrusting Polychaetae Mercierella enigmatica, Spirorbis, the Gastropods Limapontia capitata and Rissoa,

Spongiae, etc., occur only on ships travelling in geographical areas beyond the mediterranean basin ;

Table 3

Occurrence frequency of different epibiotic organisms on the Romanian ships, depending on the marine areas sailed (B.S. Black Sea; B.M. - Black Sea and the Mediterranean, OS - Black Sea, the Mediterranean and other seas and oceans)

No.	Organisms	B.S.	B.M.	O.S.
1.	Balanus improvisus Darwin	100	100	86
2.	Balanus larve	50	-	57
3.	Chtamalus sp.	-	-	14
4.	Lepadidae	-	-	14
5.	Copepoda varia	100	100	100
6.	Corophium sp.	33	-	43
7.	Tanais cavolini M.-Edw.	33	33	14
8.	Idotea baltica (Pallas)	50	33	71
9.	Turbellaria varia	33	67	43
10.	Turbellaria cocoons	83	67	29
11.	Nematoda varia	100	100	100
12.	Polydora sp.	17	-	14
13.	Mercierella enigmatica Fauvel	-	-	71
14.	Spirorbis sp.	-	-	14
15.	Serpulidae varia	-	-	14
16.	Polychaeta varia	83	67	100
17.	Oligochaeta varia	67	33	86
18.	Mytilus galloprovincialis (Lamarck)	50	67	71
19.	Cardium sp.	50	33	43
20.	Petricola lithophaga (Retgius)	17	67	43
21.	Bivalvia veliconches	67	67	100
22.	Embletonia pulchra Alder et Hancock	17	33	43
23.	Limapontia capitata (O.F. Müller)	-	-	14

No.	Organisms	B.S.	B.M.	O.S.
24.	Rissoa sp.	-	-	14
25.	Gastropoda veliconches	50	67	57
26.	Foraminifera varia	33	-	14
27.	Vorticellidae varia	17	-	29
28.	Porifera varia	-	-	14
29.	Obelia loveni (Allman)	17	-	29
30.	Hydrozoa varia	83	-	43
31.	Lepralia pallasiana (Moll.)	-	-	14
32.	Membranipora denticulata Busk	-	-	43
33.	Victorella pavida S. Kent	-	33	29
34.	Bryozoa varia	33	-	-
35.	Halacarida varia	33	-	-
36.	Algae	67	100	86

- of the organisms identified, 61% are sessile, typically epibiotic, and 39% vagile using as vital space the interstices stilted with sediments, present among the communities of fixed species;

- the organisms found on the 16 ships studied are mostly euryhaline; without any indication on their origin, we mention that all of them, excepting the Lepadidae, are inhabitants of the Black Sea;

- the algae occurrence has a high frequency (67-100%) on the ships studied and they include macrophyte species (especially Ectocarpus and Enteromorpha) epiphyted by on abundant microflora (especially Diatomea: Melosira moniliformis, Synedra ulna, Lichmophora ehrembergii, Achnanthes brevipes, Achnantes longipes, Navicula pennata var. pontica and Navicula sp.

We emphasize that, qualitatively, there is no variation in algae species as related to the geographical areas crossed by the ships; the identified species are widespread in many marine basins, frequently encountered in shallow areas.

If qualitativelly there is a great similarity between the foulings of the Romanian ships which sail in different geographical areas, quantitatively, important differences are found from one ship to another. Even on a single ship, the community of epibiotic organisms is quantitatively differently arranged on the keel. The reasons for these quantitative variations are numerous and, at the same time, difficult to assess, requiring continous observations and records, in time and space, with regard to the deposition and the evolution of the fouling on the keel. Certainly, when we are analyzing an already constituted fouling, as in our case, the elements to take into account for interpretation purposes are those related to the utilization rate of the ship: the time span between two dockings (days at sea and days on berth), as well as the geographical areas crossed.

In the following, we shall analyse some quantitative aspects of the fouling, as related to the utilization rate of the Romanian ships.

One of the main elements characterizing the fouling as a negative phenomenon is its weight. The larger the total weight of epibiosis on the surface unit and the heavier the covering with epibiotic organisms on the keel, the more negative the effect of the fouling on the utilization rate and the efficiency of the ship will be.

We speak of T F in the first place because it is the result, in time, of live organisms acumulated action. Over the primary layer consisting of bacteria, mushrooms and microphytes (TF=LF, but in this case, primary fouling is not a negative phenomenon), the secondary fouling begins to settle - calcareous sessile organisms of the Balanus type, incrusting Polychaetae, etc. In the first stage, the secondary fouling in an entirely live one. With the utilization of ships, with their passage through different geographical areas, with the repeated changes of some life conditions of the epibiotic organisms, one part of the fouling organisms having uderwent numerous stresses will resist, another part will die. Those who die leave their calcareous remains, shells of Balanus and mainly, tubes of worms fixed on the keel.

The calcareous crust of the tanathocenosis together with the

mineral sediments in suspension, and the organic and vegetal detritus, form a new sedimentary biotope to become populated with new organisms. Upon the incrusting tanathocenosis, other sessile organisms continue to settle on and thus, the fouling weight. That is why starting from this general scheme of formation and evolution of the fouling, we considered it necessary to discuss in the first place the total fouling (TF) and to refer only later to the live fouling (LF).

Depending on the ship size, the total charge of fouling strongly varies, from 8 kg. ("Dolj", a ship with 10.000 tons displacement, where the fouling was limited ro the alternation area, on a 25 cm wide stripe) to 6,845 kg (Vrancea, a ship with 17,359 tons displacement, of ships, we obtained very low and variable values; their order of magnitude ranges between a few hundredths of thousandth (0.000079% TF of the displacement of the ship "Dolj") and a few tendths of thousandths (0.362 % TF of the displacement of the ship "Titan") (table 4). Despite the individual variations recorded, if a mean value were computed according to the geographical areas crossed by the ships, the ratio TF - displacement found, would amount to:

- 0.153 for ships operating in the Black Sea;
- 0,031 for ships operating in the Black Sea and in the Mediterranean ;
- 0,012 for ships also operating beyond the Mediterranean, on other seas and oceans.

These mean values led us to a very important conclusion: the more numerous the geographical areas crossed by a ship, the smaller its fouling charge will be.

Again, starting from the total fouling on the ships, as related to the keel surface covered, we obtain the mean weight of the fouling on 1 m^2 (table 5).

This value is, however, the result in time of the deposits of epibiosis on the keel, which time varies from ship to ship. Therefore to obtain comparative data, we are to use 3 variants of the mean index of

Table 4

Fouling charge (TF) on the Romanian ships studied (on the main parts of the keel-laboard, starboard, battom); ratio between TF and displacement of ships

Ships	m^2 TF x)	kg. TF larboard	kg. TF starboard	kg. TF bottom	kg. TF Total/ship	TF% of Displacement
Ships operating on the Black Sea						
ADAMCLISI	321	479	481	-	160	0,300
MAREA NEAGRA	1,060	-	-	-	1,121	0,029
RAZELM	189	0	34	-	34	0,002
DELTA	141	63	10	-	73	0,021
TITAN	1,053	220	339	890	1,449	0,362
ARIESUL	50	98	98	-	196	0,202
Ships operating on the Black Sea and the Mediterranean						
MIDIA	192	48	52	0	100	0,017
CARANSEBES	1,363	292	292	156	740	0,029
VATRA DORNEI	1,314	372	372	473	1,217	0,047
Ships operating on the Black Sea and the Mediterranean and other seas and oceans						
MAMAIA	3,062	282	282	996	1,560	0,018
OLTENIA	3,949	544	544	0	1,088	0,002
BRAD	2,704	79	4	24	107	0,002
DOLJ	47	5	3	0	8	0,000
SINAIA	5,941	617	833	1,312	2,762	0,013
VRANCEA	5,335	3,066	2,266	1,513	6,845	0,039
SUCEAVA	2..359	209	209	363	781	0,012

x) TF = surface of keel covered by fouling

(O: nofouling = : fouling uniform distributed on the keel; -: no real flot bottom ship with).

Table 5

Variation of mean index of daily depositing of fouling, depending on the total number of days when the ships were operating between two dockings (FIA) on berth (FIB) and operating on the Black Sea (FIA. BS).

No. Ships.	TF g/m^2 (media)	IFA	IFS	IFA-MN
A. Ships operating in the Black Sea basin				
1. ADAMCLISI	2,990.654	12.89	33.23	12,89
2. MAREA NEAGRA	1,057.547	0.89	3.06	4.23
3. RAZELM	179.894	7.50	7.50	7.50
4. DELTA	517.730	0.95	1.46	3.78
5. TITAN	1,376.068	2.28	2.51	3.86
6. ARIESUL	3,920.000	4.74	5.16	4.74
MEDIA	-	4.88	8.82	6.17
B. Ships operating in the Black Sea basin and the Mediterranean				
7. MIDIA	520.833	1.65	3.30	6.68
8. CARANSEBES	542.920	0.88	1.32	2.25
9. VATRA DORNEI	926.179	1.98	3.31	3.36
MEDIA	-	1.50	2.61	4.10
C. Ships operating in the Black Sea, the Mediterranean and in other seas and oceans				
10. MAMAIA	509.470	0,61	0,95	1,96
11. OLTENIA	275.512	0,65	2,42	4,37
12. BRAD	39.571	0,06	0,12	0,35
13. DOLJ	170.212	0.46	0,76	2,08
14. SINAIA	464.904	0,60	1,10	2,24
15. VRANCEA	1,283,036	2,77	4,26	7,13
16. SUCEAVA	331.072	0,43	0,75	1,61
MEDIA	-	0,80	1,48	2,82

the daily depositing of fouling (FI) depending on the total number of the days when the were at sea (FIS), on berth (FIB) and at sea in the Black Sea (FIS-BS) (Table 5).

We choosed the three index variants, because the fouling depositing on the Romanian ships depends not only on the number of days at sea, between two dockings, but also on the periods on berth (very favourable to depositing of epibiosis) and on the period they remained on the Black Sea (the sea to which, qualitatively, the majority of epibiotic organisms on the Romanian ships belong).

The mean index of daily depositing of the fouling records large variations from one ship to another; however, a first observation may be made, namely that its values are grouped on the large areas crossed by the ships. Thus, we can say that irrespective of the utilization rate of the Romanian ships (that is at sea, or on berth) the daily mean value of fouling depositing is lower as the geographical areas crossed are more various.

In the following we shall give some characteristic examples showing how the value of the mean index of daily depositing of fouling on the Romanian ships, depends on their utilization rate.

The highest FI values were always recorded in ships which did not sail beyond the limits of the Black Sea, precisely, the Romanian shore.

The tugboat "Adamclisi" which operated in the roads of Constanţa exclusively, recorded maximum values. For 232 days, over the July 1972 and march 1973 period, the epibiotic organisms could settle and develop on the keel of this ship, under normal conditions, without stress, averaging 12.89 g/day. If we take into account only the berthing periods, the index value raises to 33.22 g/day.

The ship "Razelm" which remained in Constantza for 24 days, after having had its keel painted, showed a high enough FI (7.50 g/day).

The research ship (fishing type) "Arieşul", over a 826 days period of which 92% was on berth, took a rather abundant epibiosis, averaging 4.74 g/day. If for exemplification we take only ships from the Black Sea, showing the highest FI, we find that "Adamclisi" holds the maximum, even though she remained on berth only for 39% of her activity ti. However, although "Razelm" and "Arieşul" had a longer berth

period, percentage, they were stationed in Constantza and Tomis, harbors where the epibiotic organisms were scarcer and which are, to a large extent, polluted. The slow speed, the limited travelling area of the tugboat "Adamclici" (in the roads of the harbor Constanţa) favoured the increase of contact with the larvae of epibiotic organisms, hence the possibility for a higher rate of fouling deposition. If we raise for discussion the lowest FI values of the ships operating in the Black Sea - f. inst. the dredge "Marea Neagră" or the crane "Titan", we readily find that these low values are the result of a long time activity on the Danube.

The analysis of ships reaching the Mediterranean only, showed the highest FI value recorded by the ship "Vatra Dornei" (1.98 g/day) and the lowest value, by the ship "Caransebeş" (0.88 g/day). The difference of values is due to the fact that while "Vatra Dornei" did not enter the fresh waters (its fouling accumulating progressively), "Caransebeş" operated on the Danube for 9% of its activity time The ship "Midia" also operated on the Danube for an equal percentage, and yet, the FI value is higher. In this case, we believe that only the operating time between two dockings, approximately twice as high in "Caransebeş" than in "Midia" accounts for the destruction of the fouling formed (probably under its own weight, and especially by the penetration of the ship in fresh waters).

Among the ships wich sailed beyond the Mediterranean limits, we mention "Vrancea" with the highest FI value (2.77 g/day) and "Brad" with the lowest value of this parameter (0.66 g/day). Let us comparatively analyse these two extreme values. The ship "Vrancea" which recorded the highest F.I. value as against the number of activity days, was on berth over a higher period, than "Brad"; the mean index of daily depositing being much higher on berth: 4.26 g/day (Vrancea) - 0.12 g/day (Brad). Even more telling are the values if we refer to the periods when these ships operated in the Black Sea area: 7.13 g/day (Vrancea) - 0.35 g/day (Brad). We may also take into account the fact that "Vrancea" sailed in fresh waters only for 6% of the total number of days between two dockings, whereas "Brad" did in a proportion of 21%. All the above

demonstrate that the fouling settles on the ship keels more rapidly when they are on berth and avoid the fresh waters.

The values of the mean index of daily depositing of fouling on the Romanian ships recorded by us are much lower than those given on the literature. In the Baltic Sea, stationed on the buoys, values of 21-58 g/m^2/day were recorded (Arbuzova, 1963; Zevina, 1972); on the Barentz Sea, the value of 7.3 g/m^2/ day was recorded on ships (Zevina, 1972) (a value approaching those found by us on the ships in the Black Sea); in the Black Sea, Morozova - Vodeanitzkaia (1936) recorded a value of 172 g/m^2/day (a value which seems very ligh for a period of only 90 days), and Dolgopolskaia (1954) recorded on experimental plates, under stationary conditions, 150-292 g/m^2/day.

We must not be surprised by these high values because most of them are limited to restricted marine areas. Thus, the low values recorded by us on the Romanian ships are due to the various environmental conditions to which the epibiotic organisms have been exposed to the dynamic factors of the fouling formation, as well as to some special conditions of the substrate considered, that is a keel of ships painted with antivegetative substances.

Summarily analysing the percentage values of live fouling of the total fouling, we find some interesting aspects. The participation of the biomasses of epibiotic communities in the forming of the total fouling, largely varies not only from one ships to another, but also between the different parts of the keel of a single ship. Thus, the fouling participes in the forming of the total fouling in a range varying between 0.14% ("Oltenia") and 95.82% ("Adamclisi"). The mean value, on ships, ranges between 1.19% and 74.55%. The low rates of the live fouling show that the ships underwent stressing conditions, determining the decimation of an important part of the epibiotic communities. The analysis of the mean values shows that the more various the geographical areas crossed by ships, the larger the destruction occureed among the populations of epibiotic communities. Thus, the value of live fouling percentage of the total

fouling declines in parallel with the increase ot the ship radius of action: 51.16% for the ships which do not sail beyond the limits of the Black Sea (Romanian shore), 43.39% for the ships reaching the Mediterranean, and 30.28% for those which sail beyond the limits of the Mediterranean.

Fouling distribution on the ship keel depending on their utilization rate

On the 16 ships studied, we found that only on two, the fouling showed a uniform distribution, covering the whole keel ("Marea Neagră" and "Arieşul"). On most ships, the fouling is differently deposited on the ship (Table no. 6), depending on the utilization rate and on the technical characteristics in the construction on each ship.

In the following we shall give some data concerning the quantitative location of the fouling on the different parts of the keel.

On the boards, the fouling is more or less uniformly deposited; the differences recorded between larboard and starboard are due to the frequency with which the ship was berthed at the same board or to some particular conditions (presence or absence of outlets for the cooling water or sewage on the ship) on the bottom the fouling is scarcer than on the boards, or totally absent (in large ships with adequate draught) (Table no. 6). We consider this instance as normal, due to the special conditions on these points of the keel (reduced light, scarce organic suspensions - hence reduced food, poorer oxygenation, etc.).

On most ships (excepting the small ones) the fouling is better developed in the stern area than in the prow area (where the epibiosis lacks).

The alternation areas, due to their particular conditions (alternation of immersion and emersion, while the ship is loaded or unloaded, oxygenation and strong lighting, a.s.a.) allow for the depositing of a very peculiar fouling, dominated by the presence of algae.

Table 6

Mean biomass (g/m^2) of total fouling on the different keel parts of the Romanian ships studied

No.	Ships	Bottom	Larboard	Starboard	Prow	Stern	ZA
	A. Ships operating on the Black Sea						
1.	ADAMCLISI	3,400	2,542	2,600	3,438	3,275	2,538
2.	MAREA NEAGRA	=	1,058	=	=	=	=
3.	RAZELM	-	0	212	=	=	280
4.	DELTA	-	889	141	=	=	=
5.	TITAN	890	1,738	2,675	=	=	=
6.	ARIESUL	-	3,944	=	=	=	=
	B. Ships operating on the Black Sea and the Mediterranean						
7.	MIDIA	0	476	725	311	345	527
8.	CARANSEBES	217	661	661	493	677	?
9.	VATRA DORNEI	688	1,340	1,340	796	2,235	?
	C. Ships operating on the Black Sea and the Mediterranean and other seas and oceans						
10.	MAMAIA	647	386	386	=	=	175
11.	OLTENIA	0	210	210	0	392	?
12.	BRAD	380	1,250	726	=	=	?
13.	DOLJ	0	0	0	0	0	167
14.	SINAIA	420	426	520	=	=	?
15.	VRANCEA	550	1,812	932	1,121	=	?
16.	SUCEAVA	275	402	402	275	334	?

Explanation of marks: 0: total lack of fouling; =: the amount of fouling on relative part of the keel is equal to that on larboard or starboard; - : lack of flat bottom in ships; ?: lack of quantitative data.

Characterization of the main epibiotic organisms on the Romanian maritime ships

In the following, we will attempt to give a short characterization of the basic elements participating in the formation of the animal fouling. The sessile forms are, of course, the only elements constituting the fouling, they being basic forms of epibiotic communities, yet the high number of vagile organisms, secondarily occurring in the associations of the epibiosis of ships impose on us also their analysis. The tables 7, 8 and 9 show the maxima densities and biomasses which can be reached by all organisms which we found in the fouling of the ships studied.

Sessile organisms

The Balanidae Cirripeds are the most important group of animals in the marine fouling. In the Black Sea there are 5 species of animals belonging to this group, of which only one is a mass group, namely Balanus improvisus; as a matter of fact, except for one ship ("Oltenia") it is the only species of Balanus found in our samples.

B. improvisus is characterized by a large euryoecia, which accounts for its widespreading: all over the oceans and seas related to this, in the temperate, tropical and subtropical areas. In the Black Sea it tolerates fresh water infiltrations under 1‰ (Băcescu, Müller, Gomoiu, 1971), allowing even for reproduction. This species is able to resist even in fresh water for a period up two days, as well as in emersion, for a 4-5 days period (Zevina, 1972).

We wish to mention aside from its presence in this large distribution area, also the fact that due to its high euryhalinity, this species represents the dominant form of the fouling, in the Baltic Sea, the Sea of Azov, the Caspian Sea and the Black Sea. The densities and the biomass of Balanus improvisus in these seas show very high values. This fact is more obvious on the stationary objects: thus, in the Baltic Sea, only after 7 months, the biomass of this aspecies reached on the buyos,

Table 7

Maxima values of density and biomass of the main epibiotic organisms on the Romanian ships having sailed in the Black Sea basin

Organisms	Density spec./m^2	Biomass g/m^2
Balanus improvisus Darwin	102,125	4,802.880
Balanus larvae	46,900	4,690
Copepoda var.	417,100	8,347
Corophium sp.	75	0,030
Tanais cavolini M. - Edw.	2,875	5,750
Idotea baltica (Pallas)	925	2,775
Turbellaria var.	1,700	1,020
Nematoda var.	1,515,612	2,577
Polydora sp.	2,200	1,320
Polychaeta var.	198,600	119,160
Oligochaeta var.	14,075	2,815
Mytilus galloprovincialis	2,875	1,013,750
Cardium sp.	4,375	21,850
Petricola lithophaga (Retzius)	100	1,000
Bivalvia veliconce	116,100	11,610
Embletonia pulchra Alder et Hancock	3,000	0,600
Gastropoda veliconches	700	0,070
Foraminifera var.	1,100	0,055
Vorticellidae var.	++	++
Obelia loveni (Allman)	++	++
Hydrozoa var.	++	++
Bryozoa var.	++	++
Halacarida var.	25	0,002
Algae	++	714,750
LF maximum	1,566,038	4,806,944
TF maximum		6,250,000

Table 8

Maxima values of density and biomass of the main epibiotic organisms on the Romanian ships having sailed in the Black Sea and the Mediterranean

Organisms	Density spec./m^2	Biomass g/m^2
Balanus improvisus Darwin	38,000	38,000
Copepoda var.	108,150	2,163
Tanais cavolini M.-Edw.	975	1,950
Idotea baltica (Pallas)	25	0,750
Turbellaria var.	1,250	0,750
Turbellaria cocoons	2,188	0,022
Nematoda var.	102,600	0,174
Polychaeta var.	372,087	223,252
Olygochaeta var.	75	0,015
Mytilus galloprovincialis (Lam.)	3,600	36,000
Cardium sp.	4,925	24,625
Petricola lithophaga (Retzius)	9,600	9,600
Bivalvia veliconches	24,188	2,419
Embletonia pulchra Alder et Hancock	1,850	0,925
Gastropoda veliconches	2,300	7,820
Hegg-masses	+	+
Victorella pavida S. Kent	+	+
Green algae	++	489,000
LF maximum	+ 655,512	490,153
TF maximum		2,235,000

Table 9

Maxima values of density and biomass of the main epibiotic organisms on the Romanian ships having reached the oceans

Organisms	Density spec./m^2	Biomass g/m^2
1	2	3
Balanus improvisus Darwin	238,908	246,144
Balanus larve	19,650	1,965
Chtamalus sp.	400[x]	40,000
Lepadidae var.	50[x]	220,688
Copepoda v' r.	555,875	11,118
Corophium sp.	900	0,036
Tanais cavolini M.-Edw.	212	0,424
Idotea baltica (Pallas)	63	0,189
Turbellaria var.	3,800	2,280
Turbellaria cocoons	17,850	0,179
Nematoda var.	436,062	0,741
Polydora sp.	100	0,800
Mercierella enigmatica Fauvel	38	1,710
Spirorbis sp.	38	0,114
Serpulidae var.	12	0,096
Polychaeta var.	190,775	114,465
Olygochaeta var.	1,125	0,225
Mytilus galloprovincialis (Lam.)	5,175	51,750
Cardium sp.	6,187	30,935
Petricola lithophaga (Retzius)	9,260	9,260
Bivalvia veliconce	50,212	5,021
Embletonia pulchra Alder et Hancock	8,000	4,000
Limapontia capitata (O. F. Müller)	200	0,040
Rissoa sp.	200	0,100

x) Organisms found on a single ship (Oltenia)

1	2	3
Gastropoda veliconches	9,800	33.320
Foraminifera var.	25	0,001
Vorticellidae var.	+	+
Porifera varia	+	+
Obelia loveni (Allman)	+	+
Hydrozoa var.	+	+
Lepralia pallasiana (Moll.)	+	+
Membranipora denticulata Busk.	+	+
Victorella pavida S. Kent	+	+
Bryozoa var.	+	+
Green algae	+	475,438
LF	1,012,587	556,690
TF		2,450,000

13,2 kg/m^2 (Arbuzova, 1963), in the Caspian Sea, after 7-8 months, 22 kg/m^2 (Arbuzova, 1963) and in the Black Sea, in the gulf of Novorosiisk (47) it reached on metal plates, a biomass of 28 kg/m^2.

In all these cases B. improvisus represented over 80% of the whole biomass of the fouling (Nikitin, 1947).

In our samples collected on ships, that is on moving surfaces, travelling in areas very different in terms of ecological conditions, the biomasses and densities found, were much lower than in the above mentioned instances. Nevertheless, B. improvisus still remains under these conditions a dominant form, giving high enough biomasses and particularly densities. Thus, on most of the ships investigated, this species represents the highest amount of the animal fouling weight. This dominantion is very well marked on the ships having operated on the Black Sea exclusively (f. inst. on the "Adamclisi", the percent is 99.9%).

The density of B. improvisus is very variable ranging from a minimum of 25 specimens/m^2 (the ships "Midia" "Mamaia") to a maximum

of 246,600 - 238,908 specimens/m^2, (the ships "Dolj" "Sinaia"). We referred here only to adult organisms; if we also take account the Cypris, larvae of Balanus, freshly deposited on the keel, the density values of this species would be considerably higher. For inst. the Cypris larvae of Balanus reached densities of 11,650 spec./m^2 on the ship "Dolj" and 10,256 spec./m^2 on the ship "Sinaia". The biomass of Balanus also shows very different values: minima of 1-2 g/m^2 ("Midia", "Mamaia") and maxima of 1,030 up to 4,803 g/m^2 ("Adamclisi", "Titan").

On the ships having operated in the Black Sea exclusively, the populations of Balanus improvisus, although they do not show the highest densities, are made up of individuals much larger than those on the other ships. The mean weight of a specimen is of 0,4 g on the ship "Arieşul" which was on berth in the Black Sea for 92% of the period between two dockings, a long enough time (826 days), so that Balanus could reach rather important sizes (14-20 mm), being favored by constant ecological conditions. A closer mean weight but still under 0,37 g, was found in the specimens of Balanus on the ship "Adamclisi". The lower values of mean weight of an individual are due to the shorter period between the latest two dockings, as well as to the fact that the proportion of days on berth, over this period, was lower (39%). On the other ships having operated only in the Black Sea basin, the mean weight of a specimen is much lower, depending on the sailing periods on the Danube and on the period between the two dockings. The lowest values (0.001 g) were found in the Balanus populations on the ship "Delta" which operated principally on the Danube and on "Razelm" with a 24 days period between the dockings.

On the ships having operated also in other basins, the Balanus populations are made up of small specimens, the mean weight of a specimen being mostly 0.001 g, despite the important densities recorded on some of these ships ("Dolj", "Sinaia", "Vrancea"). These populations consist of individuals deposited during the last period on berth in Constantza, before docking (f. inst. "Vrancea" with such a 86 days period,

"Dolj - 36 days, "Sinaia" - 30 days). The growth rate of Balanus, in the Black Sea, is of 8 mm in the first 30 days (Dolgopolskaia, 1957); consequently, these populations are made up of very young individuals, the berthing in the harbor favouring the deposition of a high number of Balanus larvae. We emphasize the fact that the only ship where the species Balanus improvisus was not found, was "Oltenia", a fact which can be explained by following up it utilization rate. Thus, for 73% of the period between the two dockings the ship was at sea and for 84% of the same period she operated in other seas. In the harbour of Constantza it remained only for 12 days, prior to docking, which practically was too short a time for the species to deposit its larvae.

A comparison between the Balanus populations on artificial substrats and those on natural substrata showed that on the latter, the densities found were much lower. Thus, in the Black Sea, at Karadag, these densities did not exceed 40 spec./m^2 (Saronov, 1952); on our littoral, the maximum density found on rocky substratum in front of Agigea, was 821 spec./m^2 (Băcescu. et. al. 1963). It results that the deposition of Balanus larvae on artificial substrata develops at a very rapid and intense rate. This process is favoured by the fact that these substrata occur especially in harbours, where the motionless water permits the fixation of Balanus larvae, which, on natural rocky substrata, constantly exposed to high waves, charged with sediments and rocky fragments, are hampered.

Aside from Balanus improvisus, another species belonging to the Balanidae Cirripeds, Chtamalus sp. was found, in low densities on the ship "Oltenia" also on this ship, among the Lepadidae Cirripeds, Lepas sp. was faund. Their presence here is fully justified by the above analysed utilization rate of this ship.

The bivalves represent a group of same importance to the fouling, as the Cirripeds. The most important of this group are the mussels (Mytilus) of which Mytilus galloprovincialis occurs in the Black Sea, as well as in the Mediterranean and the eastern coast of the Atlantic ocean.

Euryhaline species, a character however less marked than in Balanus, forms very dense populations in the fouling.

The biomass of Mytilus, on stationary, submerged objects, can after several years, reach up to 100 kg/m^2, exceeding, in this respect any other organisms (Zevina, 1972).

The mussels are not dominant in the fouling from the beginning. Only after 1 or 2 years do they replace the populations of Balanus and yield high biomasses especially on stationary objects, and less on the ships. This is due, on the one hand, to the fact that the larvae of Mytilus have more difficulty in settling than those of Balanus, under motion conditions of the water, and, on the other hand, to a lower growth rate. At the same time, the presence of a prior population of Balanus, protects by their anfractuosities, the larvae and the juveniles of Mytilus against the water streams which tear them up from the keel.

Hence, in the ship fouling, the mussels do not play an important role, for several reasons:

- more reduced euryhalinity in Mytilus galloprovincialis than in Balanus;
- operating time at sea;
- period between two dockings shorter than two years, in most of the ships, hence insufficient for replacing the population of Balanus with that of Mytilus.

Thus, among the ships studied by us, the mussels represent a high percentage in the total biomass of the fouling only on the ships with on over 2 years period between dockings: "Arieşul" 59% and "Mamaia" 10-80%. The only exception, was the dredge "Marea Neagră" where Mytilus was totally absent, despite a 1,190 days period between dockings. This was but natural, because the ship operated in fresh water for 79% of this span, that is, under conditions incompatible with the occurrence of this species.

On the ship "Arieşul" who operated in the Black Sea exclusively, and was stationed for 92% of the period between the last two

dockings, the beginning of mussel domination in the fouling obviously emerged. In contrast with other ships where Balanus is dominant in terms of density, here, the number of Balanus and that of mussels and their veliconches is very close, whilst ponderally, the mussels are already dominant. "Arieşul" was the only ship among those studied by us where we found specimens larger than 5 mm, reaching 40 mm in length.

The density of bivalve veliconches, of which the majority probably belong to Mytilus galloprovincialis, depends both on the berthing period in Constantza before docking, and on the season when this period occurred. Thus, we found a maximum density - 116,100 spec./m^2 - on the crane - ship "Titan" who operated for 247 days in the harbor of Constantza before docking, and high values were also found on the ships "Vatra Dornei" - 24,188 spec./m^2 - and "Vrancea" who stationed in the harbor, for 45 and days respectively, before docking. These three ships were on berth, over May, June and July, when the density of veligerous larvae reaches a maximum in the plankton. On the "Mamaia", despite a 55 days berthing period, the bivalve veliconches are absent or very scarce, because in February and March, when the ship was on berth, the veligerous larvae are absent or very scarce in the plankton.

The other bivalves we found in the fouling of ships, Petricola lithophaga and Cardium sp., showed a still more reduced quantitative importance due both to their density and to the fact that the specimens found were juveniles.

The Bryozoa are well represented in the fouling, yet without playing a dominant role in the epibiotic communities on the ships. This is due to the fact that the Bryozoa species encountered in the fouling, despite their characteristic resistance to, or even preference for pollution, avoid the motioning conditions of the water (Zevina, 1972).

Among the ships investigated, the denser Bryozoa populations were found on the ship "Arieşul" who stationed for 92% of the period between the dockings, on the "Adamclisi", who stationed and sailed at low speed in the roads of Constanţa exclusively, as well as on the ship

"Vrancea" who stationed for 86 days in the harbor of Constantza before docking.

Among Bryozoa, the most frequent species was Membranipora denticulata followed by Victorella pavida and Lepralia pallasiana, who showed a much lower frequency.

The difficulties in a quantitatives assessment of the Bryozoa populations did not allow for accurate values of their biomass, which therefore remained included in the total fouling.

It is worth mentioning that along with Balanus the Bryozoa change the appearance of the artificial substratum, in that, that by the asperities created they made it favourable to polluation with ever more epibiotic organisms.

Just like in the previous group, no quantitative assessment could be made in Hydrozoa. Nonetheless, we can evaluate their contribution to the fouling weight, as being of little importance, even when the populations were well represented. This was due both to the absence of calcareous skeleton and to the fact that in our samples Obelia sp. was dominant, a species forming small size colonies. The highest number of these colonies were found on the ships having sailed in the Black Sea exclusively (except for "Razelm" who had but a 24 days period between dockings), as well as on the ship "Vrancea", among those who also sailed in other seas, where the colonies probably occurred during the last 86 days berthing period in the port.

The Polychaetae serpulidae, which in tropical and subtropical seas are even dominant forms in the fouling, are of little significance in the Black Sea. We found but a few spec./m^2 of Mercierella enigmatica on some of the ships having sailed in the Black Sea and other seas, and Spirobis sp. on a single ship (Mamaia).

Vagile organisms

As we already showed, the settlement of sessile fauna changes the even appearance of the ship surface, forming numerous anfractuositres,

which become stilted with sediment, creating favourable conditions for a further depositing of sessile fauna, and, at the same time, for the occurrence of an abundant vagile fauna.

Of this fauna, the only important group, not only in terms of density but also as biomass, are the Polychaetae, and among these, Polydora ciliata. The high densities of this species are due in the first place to its ability of rapidly settling on the substrate, almost as rapid as Balanus. This process was very obvious on the ship "Razelm" where only, in the 24 days between dockings, 72,438 spec./m^2 were deposited, making up for 28% of the total fouling biomass. The highest densities, however, have been found on the crane-ship "Titan", the ships "Vatra Dornei" and "Vrancea" (198,600 spec./m^2, 372,087 spec./m^2; 190,775 spec./m^2 respectively), who had the longest berthing period in the harbour, before docking, during the hot season, when the density of nectochaetae larvae in the plankton reaches its maximum.

Among the other element of vagile fauna the highest densities have been recorded by nematoda and copepoda. Due to the small size of these organisms, their biomass is negligible. The copepoda rapidly settle in the fouling, reaching huge densities in a very short time. We still take the "Razelm" as an example where, in 24 days, the copepoda density reached 417,100 spec./m^2 (82% the general density of the fouling organisms).

The Nematoda are slower in populating the ships keel, as their presence depends on the accumulation of a high quantity of sediment. The highest densities were reached ba the ships who have the longest period between the two dockings and who had longest berthing period in the Black Sea. The highest number of specimens/m^2 was found on the "Arieşul" - 1,515,612 spec./m^2 (96.8% of the general density of the fouling organisms); high densities have been recorded on the crane-ship "Titan" and the dredge "Marea Neagră" also.

As the density of Nematoda increases, the number of Copepoda

decreases, on the ships with the highest densities of Nematoda, that is those stationed the longest time in the Black Sea, the Copepoda are less numerous. For instance, on the "Arieşul" 14,600 spec./m^2 were found, which was but 0.9% of the general density of the fouling organisms.

The other groups of vagile animals showed a very low quantitative share in the fouling. Of these, the Turbellaria and particularly their cocoons the Nudibranchia Gastropod Embletonia pulchra lured in the fouling by the Hydrozoa on which it feeds, as well as the crustaceans Tanais cavolini and Idotea baltica showed a higher frequancy.

CONCLUSIONS

1. On all Romanian maritime ships, irrespective of the area crossed, the epibiotic organisms consist mostly of the same species; in the fouling composition, 36 organisms types have been identified. The great majority of organisms which constitute the epibiotic communities on the Romanian ships, were benthic species, common in the Black Sea.

2. The ponderal dominance in the fouling on the Romanian ships in represented by sessile organisms: Balanus improvisus, Mytilus, incrusting Polychaetae (Mercierella enigmatica, Spirorbis, Serpulidae) green algae, basic forms of the epibiotic communities; the vagile organisms (Copepoda, Nematoda, a series of Polychaetae worms, etc) despite their high number, always, dominating the densities of the sessile species, ponderally, are less important (due to their very small size).

3. On the basis of the ratio between the total and the live fouling, we were able to find that the more various the geographical areas travelled by the ships, the larger the destruction in the populations of the epibiotic communities.

4. Taking into account the ratio between the fouling quantity on keel surface unity and the total number of days between two dockings (mean index of daily depositing of fouling) it was found that irrespective of the utilization rate of the Romanian ships (at sea or on berth) the

daily mean of fouling deposition gets on ever lower value, as the geographical areas travelled are more various.

5. The results of quantitative assessments confirm the fact that the fouling deposition on the keel of the marine ships is more rapid under the conditions of a longtime berthing and of avoiding the fresh waters.

6. Except for the small ships, who have a constant utilization rate and are operating in a limited area, on all maritime ships, the fouling is nonuniformly, and in a differential manner deposited on the keel.

7. Due to the multitude of stressing factors influencing the epibiotic communities on the ships studied, the fouling on these ships is poor both qualitatively (low number of species - only euryhaline and eurytherm ones) and quantitatively (the fouling load on the ships is very small as compared with displacement).

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