ON FISH REARING IN THE "OCEANARIUM"

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Recently, big tanks have been built for sea animals at some aquaria in Japan and in these tanks some new rearing and displaying methods of sea animals that are inaccesible in ordinary aquaria, are being realized.

The writer was taking charge of fish rearing in big tanks of the Natural Aquarium of Misaki Park near Osaka from 1957 to 1961, and so he is going to offer here some problems he met with in fish rearing in big tanks together with some data gained during his works.

The "Oceanarium" was built at the first time in 1938 at Maiami, U.S.A. and named "Marine Studio". In Japan, the Natural Aquarium of Misaki Park, built in 1957, is the first one to have such big tanks.

Although some porpoises and sea-lions are kept in some of them to perform some tricks as a show, here in this paper descriptions are given solely on the marine fish rearing in big tanks.

Before going further, the writer wishes to express his sincere gratitude to Mr. Kunio Horike, the Director of the Natural Aquarium of Misaki Park and the planner of the first oceanarium in this country, for his kind supervision during the couse of the witer's works at that aquarium, and also to Dr. Takasi Tokioka and Mr. Eiji Harada of the Seto Marine Biological Labolatory of Kyoto University for their kindness in reading the paper. He also wishes to thank to Mr. Ryônosuke Okuno of the Suma Aquarium, Mr. Yoshimitsu Arakawa of the Miyajima Aquarium and Mr. Seiji Inoue of the Naruto Aquarium for their valuable advices and their kindess in offering him important data.

I. Main oceanaria in Japan

Big tanks made in Japan for marine fish rearing are shown in Table 1.

II. Structure of oceanarium

As an example, the general design of No. 2 Pool of the Natural Aquarium of Misaki Park is shown here in Figures 1 and 2.

The circulation system of sea water, way of physical and chemical regulation

Table 1.
Main oceanaria in Japan

name of aquaria	MIYAJIMA	SUMA	NARUTO		MISAKI PARK	
name of tanks	Open-air Pool	Aqua-land	Large Pool		No.1 Pool	No .2 Pool
shape	oval	oval	square	square	square	square
size (m.)	26×15	19×17	9×5	9×5	15×9	13.4×7.5
area (sq. m.)	270	120	45	45	135	101
deph (m.)	2.7~3.5	2.7 (3.0)	2.2	2.2	2.5 (3.0)	2.2 (3.0)
capacity (tons)	808	324 (360)	100	100	338 (405)	220 (303)
system of sea water supply	open	closed	closed	closed	closed	closed
rate of circulation (tons/h. times/day)	300 (4.5)	80 (5~6)	25 (6)	25 (6)	60 (5)	50 (6)
size of side observation window (m.)	1.0×1.0	1.0×0.8	1.0×1.0	1.0×1.0	1.2×1.2	1.2×1.2
number of windows	5	10	10	10	18	14
place	outdoor	semi-outdoor	indoor	indoor	indoor	indoor
main animals usually reared	sharks, stingrays yellow-teils	sharks, rays yellow-teils reaf fishes	sharks, rays reaf fishes	sharks, rays reaf fishes	sharks, rays yellow-teils, jacks turtles	reaf fishes
big animals once reared	turtles, sunfish indian porpoise	batrrays butterflyray	giant-ray	giant-ray	dolphins giant-ray sunfish	giant-crubs

of water, plan of illumination and design of aquarium senery in big tanks are fundamentally the same as those adopted in the ordinary aquarium, though the much greater volume of these tanks must always be remembered whenever the problems are discussed.

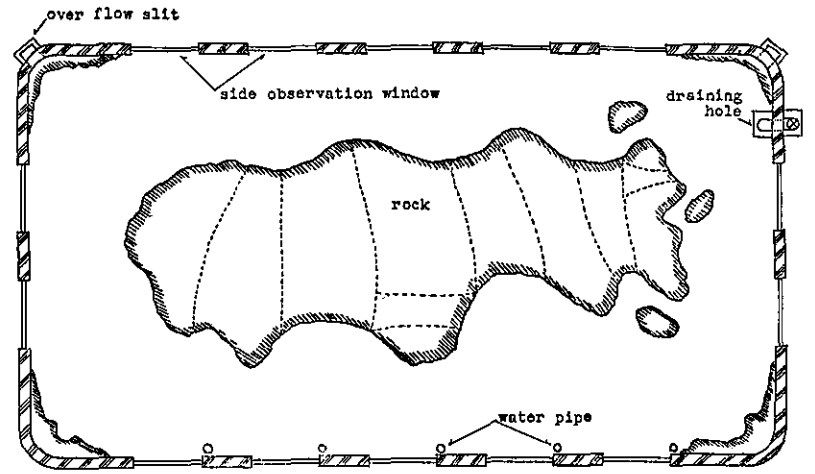

Figure 1. Plane figure of No. 2 pool

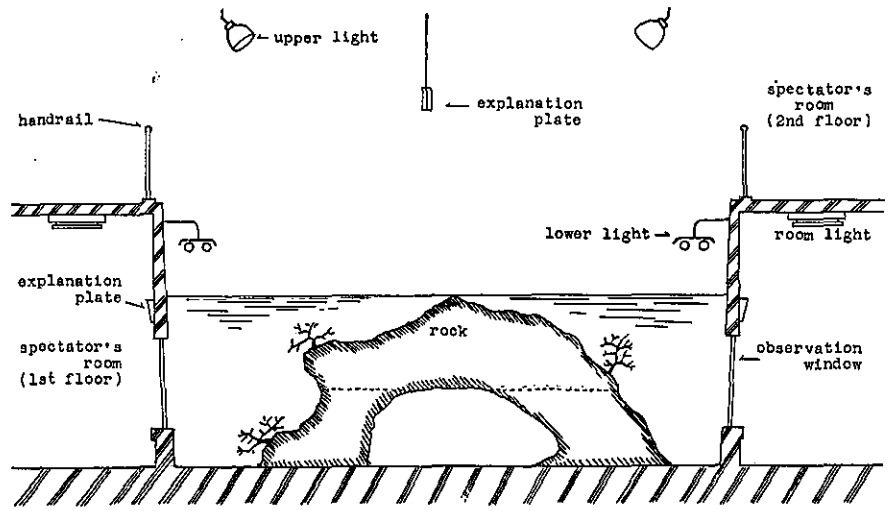

Figure 2. Section of No. 2 pool

III. Fish rearing in big tanks

1. Animals reared

Marine Animals reared in big thanks of the Natural Aquarium from 1960 to 1961 are shown in Table 2 and 3.

Table 2.

Animals reared in No. 1

	species \ years and months	1960 1	2	3	4	5	6	7	8
fishes	*Heterodontus japonicus* (DUMÉRIL)								
	Cephaloscyllium umbratile J. & F.				7	6			
	Orectolobus japonicus REGAN	1	1	1	1	1			
	Triakis scyllia MÜLLER & HENLE	6	6	5	7	8	8	7	7
	Mustelus griseus PLETSCHMANN	20	20	20	25	25	25	25	25
	M. manazo BLEEKER								
	Rhinobatos schlegelli (M. & H.)					1	1		
	Squatina japonica BLEEKER								
	Dasyatis akajei (M. & H.)			12	21	21	20	11	11
	Holorhinus tobijei (BLEEKER)	2	2	2	1	1	1		
	Seriola quinqueradiata T. & S.			48	48	47	47		
	S. purpurascens T. & S.								
	Trachurus japonicus (T. & S.)	650	640	1040	1000	80			
	Chrysophrys major T. & S.				3	3	3		
	Plectorhynchus cinctus (T. & S.)	1	1	1	1	3	3	2	3
	Echeneis naucrates LINNE								
turtles	*Caretta caretta olivacea* E.	3	3	3	3	3	3	3	3
	Chelonia japonicus (THUMBERG)								
	number of species	7	7	9	11	12	9	5	5
	total number of specimens	683	673	1132	1117	149	111	48	49

Pool from 1960 to 1961

1960 9	10	11	12	1961 1	2	3	4	5	6	7	8	9	10	11	12
						1	1	1	1						
					3	7	2								
7	7	7	7	7	7	7	7	7	7	7	5	2	2	2	2
25	25	25	25	25	25	27	27	27	27	27	22	11	11	11	11
						3	3	3	3	3	1				
							1								
						2	3	2	2	1					
8	8	8	8	8	7	12	15	14	12	10	10	10	3	2	2
								1							
20	20	10	1			1	1	1	1	1	1	1	2	2	2
30	30	20	10										4	4	4
2000	1000	950	1000	800	700	800	1700	1650	1600	1600	1600	1500	1400	1000	990
45	40	35	30	30	25	26	30	30	27	25	25	23	24	24	24
3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2
													1	1	
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
										2	2	2	2	2	2
9	9	9	9	7	7	11	13	13	11	12	10	9	11	11	10
2108	1136	1061	1087	876	770	887	1801	1744	1686	1683	1672	1553	1454	1053	1042

It is planed that No. 1 Pool holds chiefly large marine fishes and turtles, here the number of species is small, but a great number of individuals can be kept there. Contrarily No. 2 Pool is designed to hold chiefly reaf fishes of different species as many as possible.

The great space of these tanks brought a success in keeping large fishes such as Batrays, Giant conger-eels, White sharks etc., which had never been kept for so many days in small tanks, for an enough long. In addition, the schooling behavior of some pelagic fishes such as horse-macherel and yellow-teil was observed in No. 1 Pool, while the territory formation was clearly studied on some reaf fishes in No. 2 Pool.

On the other hand, it is inevitable that weak smaller fishes are preyed by voracious bigger ones. Therefore, small fishes must always be recruited also in a way to supply food for large fishes.

2. Feeding

Fresh meat of horse-macherel, clam or red prawn was used as main food for fishes reared in the oceanarium. In addition to the food provided regularly, some kind of algae growing on the tank wall and rocks are concidered to be indespensable natural food for hervivorous fishes such as *Girella punctata* GRAY, *Goniistius zebra* (DÖDERLEIN), *Prionurus microlepidotus* LACÉPÉDE etc.. Consequently, these fishes survive much longer in the oceanarium than in the ordinary aquarium.

If the food is given little by litte, it may be taken solely by stronger or smart fishes and then weaker or tardy ones are always missing it. In order to distribute the food evenly to every individual, the whole ration, with a certain amount of excess food, should be given at a time.

Daily feeding was made usually in the evening at Misaki Oceanarium.

3. Cleaning of big tanks

The inner surface of window glasses was cleaned chiefly by divers with SCUBA every three days in summer, while once a week in winter.

It is necessary to take all the animals out of the tank to wash away the bottom deposits, but this treatment is certainly very harmfull to fishes, as it might hurt fish skin and cause some fatal fish diseases. For this reason it is desirable to avoid such treatment. If the water supply in the oceanarium is enough, it can be left intact for three or four years, without any harmful effect on animals.

The raising of some scavengers like *Protosus anguillaris* (*Lacépéde*), some sea snails and crustaceans together with above-mentioned show fishes seem to be effective to dispose of food remnants.

The use of a sand-pump to sucking bottom deposits up readily without injuring fishes may be attempted.

4. Fish diseases and recruitment

Most of aquaria in Japan are, to-day, suffering from the terrible and

Table 3.

Animals reared in No. 2

Pool from 1960 to 1961

	species \ years and months	1960								1961											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
invertebrates	*Cymbactis actinostoloides* WASSILIEFF											30	70	70	70	260	500	500	500	500	500
	Tubastraea aurea (QUOY & GAIMARD)													36	36	25	10	10			
	Panulirus japonicus (VON SIEBOLD)	1	1	10	3	5	5	5	2	2											
	Macrocheira haempferi DE HAAN			7	1											4	4				
	Sepiella maindroni DE ROCHEBRUNE											48	42	15	14	12	6				
fishes	*Plotosus anguillaris* (LACÉPÈDE)	390	385	380	380	370	350	350	350	350	350	350	350	350	350	350	340	300	280	280	280
	Conger japonicus BLEEKER															1	3	3	3	3	2
	Muraenesox cinereus (FORSKAL)				1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
	Monocentris japonicus (HOUTTUYN)	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
	Trachurus japonicus (T. & S.)	130	120	100	100	80	50	8	8	150	100	130	100	80	20	1	1				
	Pseudupeneus spilurus (BLEEKER)	1	1	1	1	1	1	1	1	13	1	1	1								
	Epinephelus fasciatus(FORSKAL)	24	25	25	25	20						10	10	12	10	12	10	10	10	10	15
	E. akaara (T. & S.)	10	10	10	8	8												1	1	1	1
	E. fario (THUNBERG)																	1	1	1	1
	E. septemfasciatus (TH.)	9	9	9	8	8	1					1	3	6	5	5	5	5	5	5	5
	E. areolatus (FORSKAL)	3	3	3	3	3	1												1	1	1
	E. chlorostigma (C. & V.)																			2	2
	E. moara (T. & S.)	5	5	5	5	5	5	5	5	7	7	8	7	7	7	7	6	6	6	6	6
	Lateolabrax japonicus (CUVIER)	2	2	2	2	2															
	Diploprion bifasciatus K. & VAN H.											12	10	7	4	5	4	3	3	3	2
	Ophelgnathus fasciatus (T. & S.)	20	10	11	11	11	3	3	4	5	5	9	6	5	4	1	7	7	7	7	6
	Rhabdosargus sarba (FORSKAL)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Mylio latus (HOUTTUYN)	2	3	3	3	3	2	1		1	1	1	1	1	1	1	1	1	1	1	1
	Evynnis japonica TANAKA	1	1	1	1	1	1							1	1	1	1				
	Girella punctata GRAY	94	94	95	96	98	95	147	146	144	144	165	166	166	166	165	165	165	165	165	165
	G. mezina JORDAN & STARKS	5	5	5	5	5	5	5	10	10	10	13	12	12	10	10	7	7	7	7	7
	Kyphosus cinerascens (FORSKAL)																1	1			
	Gymnocranius gricius (T. & S.)													2	2	1	1	1	1	1	1
	Parapristipoma trilineatus (TH).	17	17	17	17	16	15	8	8	8	7	7	6	6	6	4	4	4	5	6	6
	Plectorhynchus cinctus (T. & S.)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Hapalogenys nigripinnis (T. & S.)	1	1	1	1	1	1	1													
	Lutjanus rivulatus (C. & V.)													1	1	1	1	1		1	1
	L. russelli (BLEEKER)													1	1	1	1	1	1	1	1
	Lethrinus nematacanthus BLEEKER	2	1	2	2	2															
	Goniistius zonatus (C. & V.)	7	7	7	7	7	5	3	3	3	3	3	3	7	7	8	10	10	10	10	10
	G. zebra (DÖDERLEIN)																5	3	3	3	3
	Choerodon azurio (J. & S.)																				
	Bodianus perditio (Q. & G.)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
	Pseudolabrus japonicus (HOUTTUYN)	3	3	3	3	3	2							2	2	2	2	2	2	2	2
	Callyodon ovifrons (T. & S.)																2	1	1	1	1
	Microcanthus strigatus (C. & V.)	10	10	10	10	10	10	10	11	11	11	11	12	12	12	12	12	12	12	12	12
	Prionurus microlepidotus LACÉPÈDE	5	5	5	5		3	4	4	6	6	6	5	5	5	5	5	5	5	5	5
	Balistes capistratus SHAW																			1	1
	Stephanolepis cirrhifer (T. & S.)	50	50	55	55	55	53	50	45	40	35	36	35	36	35	35	35	35	35	35	35
	Navodon modestus (GÜNTHER)	8	8	8	8	8	1	3	3	3	3	3	3	3	3	3	4	4	4	4	4
	Fugu xanthopterus (T. & S.)			7	10	10											15	7	6	6	5
	F. Niphobles (J. & S.)		1	1	1	1															
	F. rubripes (T. & S.)			5	5	5	2														
	Sebastiscus marmoratus (C. & V.)																1	1	1	1	1
	number of species	28	29	32	33	32	25	21	19	20	18	24	24	29	29	31	36	34	32	35	35
	total number of specimens	813	783	808	785	754	619	612	609	758	740	870	851	850	780	945	1187	1155	1104	1089	1089

	species \ years and months	1961				
		9	10	11	12	
invertebrates	*Cymbactis actinostoloides* WASSILIEFF	500	400	30	30	15
	Tubastraea aurea (QUOY & GAIMARD)					
	Panulirus japonicus (VON SIEBOLD)					
	Macrocheira haempferi DE HAAN					
	Sepiella maindroni DE ROCHEBRUNE					
fishes	*Plotosus anguillaris* (LACÉPÈDE)	280	280	280	280	270
	Conger japonicus BLEEKER	3	2	2	2	1
	Muraenesox cinereus (FORSKAL)	1	1	1	1	1
	Monocentris japonicus (HOUTTUYN)	1	1	1	1	1
	Trachurus japonicus (T. & S.)				2	2
	Pseudupeneus spilurus (BLEEKER)				3	3
	Epinephelus fasciatus(FORSKAL)	15	15	15	15	14
	E. akaara (T. & S.)	1	1	1	1	1
	E. fario (THUNBERG)	1	1	1	1	1
	E. septemfasciatus (TH.)	5	5	5	5	5
	E. areolatus (FORSKAL)	1	1	1	1	1
	E. chlorostigma (C. & V.)	2	2	2	2	2
	E. moara (T. & S.)	6	6	6	6	6
	Lateolabrax japonicus (CUVIER)					
	Diploprion bifasciatus K. & VAN H.	3	3	3	2	2
	Ophelgnathus fasciatus (T. & S.)	7	7	7	6	6
	Rhabdosargus sarba (FORSKAL)	2	2	2	2	2
	Mylio latus (HOUTTUYN)	1	1	1	1	1
	Evynnis japonica TANAKA					
	Girella punctata GRAY	165	165	165	165	160
	G. mezina JORDAN & STARKS	7	7	7	6	6
	Kyphosus cinerascens (FORSKAL)					
	Gymnocranius gricius (T. & S.)	1	1	1	1	1
	Parapristipoma trilineatus (TH).	6	6	6	6	6
	Plectorhynchus cinctus (T. & S.)	2	2	2	2	2
	Hapalogenys nigripinnis (T. & S.)					
	Lutjanus rivulatus (C. & V.)	1	1	1	2	2
	L. russelli (BLEEKER)	1	1	1	1	1
	Lethrinus nematacanthus BLEEKER					
	Goniistius zonatus (C. & V.)	10	10	10	10	10
	G. zebra (DÖDERLEIN)	3	3	3	2	1
	Choerodon azurio (J. & S.)				1	1
	Bodianus perditio (Q. & G.)	2	2	1	1	1
	Pseudolabrus japonicus (HOUTTUYN)	2	2	2	2	2
	Callyodon ovifrons (T. & S.)	1	1	1	1	1
	Microcanthus strigatus (C. & V.)	12	12	11	11	12
	Prionurus microlepidotus LACÉPÈDE	5	5	5	7	7
	Balistes capistratus SHAW	1	1	1	3	3
	Stephanolepis cirrhifer (T. & S.)	35	35	30	30	30
	Navodon modestus (GÜNTHER)	4	4	3	3	3
	Fugu xanthopterus (T. & S.)	4	4	3	4	4
	F. Niphobles (J. & S.)					
	F. rubripes (T. & S.)					
	Sebastiscus marmoratus (C. & V.)	1	1	1	1	1
	number of species	36	34	32	35	35
	total number of specimens	1187	1155	1104	1089	1089

	species \ years and months	1961				
		9	10	11	12	
invertebrates	*Cymbactis actinostoloides* WASSILIEFF	500	400	30	30	15
	Tubastraea aurea (QUOY & GAIMARD)					
	Panulirus japonicus (VON SIEBOLD)					
	Macrocheira haempferi DE HAAN					
	Sepiella maindroni DE ROCHEBRUNE					
fishes	*Plotosus anguillaris* (LACÉPÈDE)	280	280	280	280	270
	Conger japonicus BLEEKER	3	2	2	2	1
	Muraenesox cinereus (FORSKAL)	1	1	1	1	1
	Monocentris japonicus (HOUTTUYN)	1	1	1	1	1
	Trachurus japonicus (T. & S.)				2	2
	Pseudupeneus spilurus (BLEEKER)				3	3
	Epinephelus fasciatus(FORSKAL)	15	15	15	15	14
	E. akaara (T. & S.)	1	1	1	1	1
	E. fario (THUNBERG)	1	1	1	1	1
	E. septemfasciatus (TH.)	5	5	5	5	5
	E. areolatus (FORSKAL)	1	1	1	1	1
	E. chlorostigma (C. & V.)	2	2	2	2	2
	E. moara (T. & S.)	6	6	6	6	6
	Lateolabrax japonicus (CUVIER)					
	Diploprion bifasciatus K. & VAN H.	3	3	3	2	2
	Ophelgnathus fasciatus (T. & S.)	7	7	7	6	6
	Rhabdosargus sarba (FORSKAL)	2	2	2	2	2
	Mylio latus (HOUTTUYN)	1	1	1	1	1
	Evynnis japonica TANAKA					
	Girella punctata GRAY	165	165	165	165	160
	G. mezina JORDAN & STARKS	7	7	7	6	6
	Kyphosus cinerascens (FORSKAL)					
	Gymnocranius gricius (T. & S.)	1	1	1	1	1
	Parapristipoma trilineatus (TH).	6	6	6	6	6
	Plectorhynchus cinctus (T. & S.)	2	2	2	2	2
	Hapalogenys nigripinnis (T. & S.)					
	Lutjanus rivulatus (C. & V.)	1	1	1	2	2
	L. russelli (BLEEKER)	1	1	1	1	1
	Lethrinus nematacanthus BLEEKER					
	Goniistius zonatus (C. & V.)	10	10	10	10	10
	G. zebra (DÖDERLEIN)	3	3	3	2	1
	Choerodon azurio (J. & S.)				1	1
	Bodianus perditio (Q. & G.)	2	2	1	1	1
	Pseudolabrus japonicus (HOUTTUYN)	2	2	2	2	2
	Callyodon ovifrons (T. & S.)	1	1	1	1	1
	Microcanthus strigatus (C. & V.)	12	12	11	11	12
	Prionurus microlepidotus LACÉPÈDE	5	5	5	7	7
	Balistes capistratus SHAW	1	1	1	3	3
	Stephanolepis cirrhifer (T. & S.)	35	35	30	30	30
	Navodon modestus (GÜNTHER)	4	4	3	3	3
	Fugu xanthopterus (T. & S.)	4	4	3	4	4
	F. Niphobles (J. & S.)					
	F. rubripes (T. & S.)					
	Sebastiscus marmoratus (C. & V.)	1	1	1	1	1
	number of species	36	34	32	35	35
	total number of specimens	1187	1155	1104	1089	1089

disastrous infection of spot-disease, caused by the ciliata, *Ichthyophsirius marinus* SIKAMA parasitic in the epidermis and gills, and the oceanarium also cannot escape from the damage. The parasite attacks most kinds of marine fishes except for *Elasmobranchii* and *Apodes*. The symptom resembles that of the same kind of disease found in fresh water fishes, but it is more acute in marine fishes and differs a little in nature and degree according to the kind of hosts.

Theoretically, the greater is the volume of sea water in the oceanarium, the less is the chance of infection of this parasite. However, the isolation of infected fishes or the medical treatment of them are quite hopeless in the oceanarium. Therefore, it is the most important point to maintain the condition which never allow an explosive propagation of this parasite in the oceanarium. Actually, it must be avoided to supply a large number of newly caught fishes to the oceanarium at a time – especially the fishes easily infected by this parasite are dangerous. Even such kinds of fishes seem to become strong enough stand against the infection of the parasite or recover the health after the infection and get a kind of immunity, if they are brought into the tank little by little (less than three individuals) and acclimatized to the new environment gradually.

These were confirmed also by Mr. R. Okuno in the Aqua-land of the Suma Aquarium on *Pseudupeneus spilurus* (BLEEKER), *Lutjanus rivulatus* (CUVIER & VALENCIENES), *Choerodon azurio* (JORDAN & SNYDER), *Callyodon ovifrons* TEMMINCK & SCHLEGEL and *Fugu xanthopterus* (T. & S.). Then such phenomena may be accepted as one of the advantageous featurs of the oceanarium.

Besides, there are bubble disease and diseases caused by the parasitism of trematods and copepods; the first can be prevented by the adequate control of the water supply pump, while the latter two do not bring such a serious damage as that brought by the spot-disease.

After all, the principl of maintaining the oceanarium is quite the same as that in the ordinary aquarium, namely it is desirable to avoid to supply many newly cuaght fishes at a time, but it is recommended to acclimate these fishes in other tanks befor they are supplied in the oceanarium.

Not only the sight of the oceanarium is much more dynamic and attractive than that of the ordinary aquarium, but also the oceanarium seems to be extending the field of the fish rearing.

However, the present state of the fish rearing in the oceanarium in this country is still far from the final purpose of the oceanarium, that is to introduce the natural under-water sights into the artificial tanks. When this purpose is realized after many difficult problems are solved, the oceanarium will contribute much in fish ecology and physiology.