A Preliminary Survey of Marine Boring Organisms in Cochin Harbour.

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MARINE boring organisms destructive to shipping, particularly the Shipworms (Teredinidæ), have been mentioned by writers from early times. The first careful scientific study was made in the eighteenth century when timber in the dykes of Holland was badly attacked by shipworms, and a detailed treatise on their anatomy and habits was published by Godfrey Sellius[1] in 1733. Since then several accounts of these specialised molluscs have appeared and a multitude of species have been described differing in minor morphological characteristics. No modern biological survey was undertaken in any region until the wooden piers and jetties in San Francisco Harbour were invaded by shipworms and collapsed twenty years ago. The resulting report by Atwood and Johnson[2] which was sponsored by the National Research Council describes methods of attack which were followed in this present study. After the World War the Institute of Civil Engineers, London, also initiated a survey of marine borers, with Dr. W. T. Calman as technical adviser.[3] Specimens were sent in by members from all over the world, but these were mostly pieces of damaged wood. The British Museum has also published a very helpful bulletin by Dr. Calman.[4]

Late in 1934 it was discovered that there was only one specimen of molluscan borers in the British Museum from India. Crustacean Isopod borers from the East were also not well represented in London nor in Museums in India. With the exception of the shipworms the taxonomy of marine boring organisms has received scant attention in spite of the economic interest. It is with a view to stimulating the interest of Indian scientists in these fascinating creatures that this report is published. I am indebted to C. W. Knight, Esq., for help with the Survey, and to Dr. I. Gordon of the British Museum for identification of the Crustaceans. She could only give tentative specific names and states that Indian material should be studied further and that the Cochin specimens differ somewhat from type descriptions.

COCHIN HARBOUR.

The opportunity was taken in 1935 to make an initial survey of the marine borers in the waters in and about Cochin Harbour, Malabar Coast, South India. This is a fine natural harbour, cut off from the Arabian Sea on the west by long low sandy spits between which there is a single narrow gut some 1,500 feet wide. To the north and south the harbour is continuous with hundreds of miles of shallow brackish lagoons called Backwaters which stretch into South Malabar, Cochin State and Travancore, and receive the waters of several large rivers from the Western Ghats.

Cochin Harbour lies at about 10° North and receives the full benefit of the south-west monsoon, as well as some precipitation from the north-east monsoon from October to December. The annual rainfall is 120 inches, more than half of which falls in the four months from June to September. During and right after the south-west monsoon the water in the backwaters, and even on the Cochin shore of the harbour, some two miles from the entrance, is not salty to the taste, soap lathers easily in it and it is used by the villagers for cooking.

This study was made in the sixth month commencing with the end of April 1935. It was started just before the monsoon. Unfortunately no data were obtained on the salinity of the water in the different stations. The following information was kindly supplied by the Harbour Engineers to the Madras Government.

On 21st August 1922 the salinity of the water at the centre of the harbour gut, about 2½ hours after the inflow of the tide commenced, was 1·029 specific gravity reading.

ORGANIC GROWTH ON STEEL CRAFT.

At Seattle, Washington, U. S. A., there is a series of lakes connected with the sea. These lakes have been separated by lochs,

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[1] Sellius, Godofredus, 'Historia naturalis teredinus, seu, Xylophagi marini....' *4to Trajecti ad Rhenum*, 1732.

[2] Atwood, W. G., and Johnson, A. A., "Marine Structures, their deterioration and preservation," *Rept. of Ctte. on Marine Piling Investigations of the Division of Engineering and Industrial Research of the National Research Council*, Washington. 1924.

[3] Redgrove, G. R., Calman, W. T. and others. *1st Report of Cttee. on the deterioration of structures of timber, metal and concrete exposed to the action of sea-water.* Inst. of Civil Engineers, London, 1920.

[4] Calman, W. T., *Brit. Mus. (Nat. Hist.), Economic Series*, 1919, No. 10.

and ocean-going freighter ships are able to free their hulls of the accumulated growth which they collect by anchoring in the eastern lake where the water is fresh, the organisms die and fall off in a few days. A similar procedure is not possible in Cochin harbour because the channels are very shallow, except where they have been dredged just inside the harbour mouth. Steel barges which carry oils to Quilon, over one hundred miles to the south, and to Kottayam about 45 miles to the south, must go into dry dock every three or four months to have barnacles and oysters removed. These animals attach themselves all over the keels from about six inches below the water line. They are able to penetrate the so-called anti-fouling paint and then start oxidation in the steel plates finally causing small corroded pits.

There are no boring organisms which attack steel.

Balanus sp., the common barnacle grows slowly in Cochin harbour and vicinity and dead cases of half-grown individuals are often present. The low salinity is probably responsible for this. Nevertheless there is always an abundant supply of young animals on immersed surfaces, and there must be strains of barnacles and oysters here which are adapted to a low salinity.

ORGANISMS BORING INTO SUBMERGED WOOD.

Most of the transportation in the back-waters is done in wooden vessels called vallams. They are usually made of Venteak or Marudu wood boards sewn together with coir (cocoanut fibre) cords. It is necessary to bring these boats into dry dock about twice a year to renew planks which have become weakened by molluscan borers.

Boards which appear sound from the outside may be riddled and honeycombed with burrows within, because the molluscan borers enter the wood as microscopic larvæ. The shipworms remain in their original burrows until death and retain the first entrance point for breathing purposes. When infected wood is immersed the two short siphons of each shipworm can be seen protruding from these small holes, which are only 1–3 mm. in diameter. As soon as the wood is not submerged the siphons are withdrawn and the entrance to the burrow is closed by a ring of tissue on the siphons and by two tiny shelly scales, the pallets. The Teredinidæ are differentiated taxonomically chiefly by the morphology of these pallets. When the wood they inhabit is withdrawn from the water the molluscs keep their burrows closed and full of salt water. Thus they are able to survive for even fourteen days.[3] Bhum[5] found that *Teredo navalis* L. was able to survive in a low lethal salinity so long that after thirty-three days 10% of the animals were still alive.

Table I shows the borers which were found in seven pieces of wood from different places around Cochin harbour in April and May 1935. Two genera of the Teredinidæ were present. Teredo with simple pallets, and Bankia (syn. *Xylotria*) with compound pallets. No large individuals of Teredo were found, and this genus is evidently more intolerant than Bankia of brackish water, although Miller[10] found the opposite to be true in California; Calman[4] states that Teredo will not flourish in brackish water. Molluscan borers belonging to the family Pholadidæ are very abundant in the Cochin waters, they were present in every wood specimen. These have been identified as *Martesia striata* L., by G. I. Crawford, Esq., London. This borer has a cosmopolitan range and is abundant everywhere in the tropics (Miller, 9, plate 8). Although Martesia were obtained three miles out to sea, they were also abundant in logs lying in only slightly brackish water in the Tatapuram boat basin (see Table I). The Pholadidæ have short bodies which are completely invested in the scabrous shells. The shells of young Martesia resemble those of young Teredo, but there are no pallets. There is a pair of small accessory plates between the valves of the shell on the dorsal surface, and also a larger ventral plate in Martesia. These borers are drop shaped and fit closely into their burrows, where they form plugs just under the surface of the wood until they die. In the adults a shelly dome continuous with the valves covers the foot and prevents further boring. The largest Martesia were 1½" long and about ¾" thick near the base.

The absence of Teredinidæ in the old cocoanut-piles from the Standard Oil Company's Jetty may be attributed to the turbid shallow water there. Shipworms cannot thrive in turbid or sewage polluted water,[3] but such conditions do not deter Martesia.

[5] Bhum, H. F., *Univ. of Calif. Publ., Zoo.*, 1922, **22**, Pt. 4, p. 349.

TABLE I.

Boring organisms found in submerged wood, Cochin Harbour, April 1935.

Type of wood, location and time immersed.	Teredinidæ.	Pholadidæ.	Crustacean Isopoda and other borers.
Poon wood. Dolphins beside dry dock, Willingdon Island. 10 yrs. Copper sheathed.	*Bankia setacea*, 2 : 19″ and 21″ long, also empty burrows.	*Martesia striata*, 1 adult.	*Sphæroma terebrans* and *S. Annandalei*, very numerous.
Marudu plank. Jetty, N. E. Willingdon Isl. 2 yrs.	Burrows, 1 large, several small, empty. *Teredo diegensis* Bartsch, 1, young, ½″ long.	None.	*Sphæroma terebrans*, very numerous, burrows to ¾″ deep. Polychæta, 1.
Teak. Edge of pile, Vypeen reclamation. 2 yrs.	None.	*Martesia* adults, heavy infection.	*Sphæroma terebrans*, several.
Teak. Channel buoy, 3 mls. out. 6 months.	,,	*Martesia striata*, several young and adults.	None.
Marudu. Plank from vallam. 6 months.	Few empty burrows 6″-10″ long.	*Martesia striata* · L., heavy infection, adults.	Polychætæ, 2 large adults.
Cocoanut wood pile, Standard Oil Co. Jetty, 2½ mls. N. E. of harbour. 5 yrs.	None.	*Martesia striata*, many adults.	None.
Eriodendron log. Boat basin, Tatapuram, 2 mls. N. E. of harbour. 4 months.	,,	*Martesia striata*, heavy infection with half-grown animals.	,,

There is also a Crustacean Isopod borer which causes a great deal of damage, particularly to docks and piers in Cochin, and which belongs to the widely distributed genus Sphæroma.[4] Sphæroma is common in the tropics and in the southern hemisphere and is a relative of the smaller Limnoria or "Gribble" of northern waters. Specimens from Cochin have been identified as *S. terebrans* Bate, and as *S. annandalei* Stebbing.[6] These Crustaceans do not usually attack floating timber. Unlike Limnoria, Sphæroma can thrive in almost fresh water.[3,7] They are very destructive and often form colonies where the burrows are twelve to sixteen to the square inch. The burrows are visible from the surface, and are from ¼″ to 1″ in depth and up to 1/5″ in diameter with straight sides. Adults swim about and can leave their burrows at any time and attach themselves to a fresh piece of wood. They begin to bore in any cranny or flaw, and were often found in empty barnacle shells. At mating time a male shares a burrow with a larger female. Females were seen in August with brood pouches full of young, and they probably breed throughout the year.

[6] Stebbing, T. R. R., *Rec. Ind. Mus.*, 1911, **6**, Pt. 4, 81–182.

[7] Miller, R. C., *Ecology*, 1926, **7**, No. 3, 247–254.

TRAPS FOR MARINE BORERS.

Traps were constructed as directed by Atwood and Johnson.[2] Each consisted of seven blocks of wood, 10 × 4 × 2½ inches, attached to an upright post. These were immersed at three stations :—(1) Traps I and II off the north-east shore of Willingdon Island Reclamation in the centre of the harbour ; (2) Traps III and IV off British Cochin near the harbour entrance where the water was saltiest ; (3) Traps V and VI at the mouth of the Government Canal, two miles north-east of the harbour entrance at the Burmah Shell Company's jetty. *At stations 1 and 2 two traps* were set, one of hard Marudu wood and one of softer Venteak. At station 3, both traps were of Marudu, one untreated, the blocks of the

second had been soaked in an oil preservative. Growth was found to be so slow that it was unprofitable to examine the blocks more often than once in two months. The data from these examinations are shown in Table II, for Traps I to IV. After seven months, three remaining blocks from each trap were shipped to Madras, where I examined them. They had been *en route* for five days, yet all organisms were still alive.

On all traps, blocks number 4 were about half way between high and low tides, ordinary spring tides; blocks 1–5 were always exposed at low tide, and blocks 6 and 7 only at spring tides; blocks number 1 were barely covered at high tides.

An indication of the quantity and quality of the surface growth on the blocks is given in Table II, column 2. It has been observed that this growth accumulates far more rapidly in traps laid down off Madras in the Bay of Bengal than in Cochin Harbour. Professor R. Gopala Aiyar agrees that the low salinity in Cochin is probably responsible for the slow growth there.

Efficiency of Oils in Preserving Marine Structures.

Fish oil and bitumen are used locally in Cochin to protect wooden craft against marine borers. Two traps of Marudu wood blocks were set in the water at the Burmah Shell Jetty on June 1, 1935; one was of untreated wood, the blocks of the other had been soaked in a mixture of one part fish oil and one part bitumen. The water at this station is almost fresh after the monsoon, and is turbid with silt and sewage. After two months, on August 1, blocks number 4 were removed. There was a sparse surface growth of barnacles and algæ (*Chætomorpha linum* Fl. Dan.; *Caloglossa leprieuru* (Mont.) J. Ag.; *Microcoleus cthonoplastes* Thuret.*) but no borers were seen. After three months, in September, blocks number 5 were examined. The surfaces were covered in fine silt and there was scarcely any organic growth. No borers were found in the untreated block. The treated block contained several small burrows of *Martesia striata* 1/16 inch in diameter, on all surfaces, a few of which were dead. A few *Sphæroma terebrans* had also started to burrow in flaws and cracks in the wood. In October, after four months immersion, blocks number 6 were examined. The untreated block contained several scattered young Martesia burrows on all surfaces. The treated block also contained Martesia, but fewer than the untreated block. A few Sphæroma had burrows to $\frac{1}{8}''$ deep in the treated wood. While dissecting the blocks it was obvious that the oil treatment had softened the wood, thus facilitating penetration.

Periodicity and Growth of Marine Borers.

1. *Sphæroma terebrans* and *S. annandalei* were always active. They attacked blocks from 8″ below to $2\frac{1}{2}'$ above low water ordinary spring tides.

2. *Martesia striata* larvæ were present from April to October. They attacked blocks from 6″ to 2′ above low water ordinary spring tides. They attacked softer wood more readily than harder, but not until the blocks had been immersed over two months.

3. *Teredo* spp. larvæ were present from May to September. They attacked blocks 1″ below and 9″ above low water ordinary spring tides. They also attack softer wood first and grow twice as fast in Venteak as in Marudu. No infections were found until wood had been immersed for more than two months. Growth was very slow, burrows were only four inches long in Venteak after five months immersion. Miller[8] reports a similar growth rate for Bankia in California, but much faster rate of growth has been reported by others for the coasts of North America and elsewhere.[4,9] Again the low salinity after the monsoon is no doubt responsible. A variety of pallets of Teredo were found, and these have been tentatively identified according to the key of Hill and Kofoid[11] and Miller's figures[10] as belonging to four species; *T. diegens is* Bartsch, *T. furcillatus* Miller, *T. navalis* L.

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* I am obliged to Prof. M. O. Parthasarathy Iyengar for these identifications.

[8] Miller, R. C., *Uni. of Wash. Publ. in Oceanography*, 1935, **2**, No. I, pp. 1–18.

[9] White, F. D., *Contrib. to Canadian, Biol. and Fisheries, N. S.*, 1929, **4**, 1–25.

[10] Miller, R. C., *Univ. of Calif. Publ. in Zoo*, 1924, **26**, No 7, 145–158.

[11] Hill, C. L. and Kofoid, C. A., *Final Report of San Francisco Bay Marine Piling Cttee.*, Univ. Calif. Press, 1927 (Key to *Teredinidæ* by Bartsch).

TABLE II.

Growth found periodically in wood blocks of traps set in Cochin Harbour.

TRAP I. VENTEAK, AT EXECUTIVE ENGINEER'S JETTY, NORTH-EAST END OF WILLINGDON ISLAND. IMMERSED 24TH APRIL 1935.

Block examined, date and time immersed.	Surface growth.	Borers present.
*4, 22nd May. 1 month (renewed)	Barnacles—sparse. Green alga, *Chætomorpha*. Crustacean larvæ.	None found.
*4, 20th July. 2 months (renewed).	Alga—*Rhizoctonia*, sparse. Thick growth of small barnacles, and Diatoms. Crustacea and Polychætæ.	,,
*5, 20th July. 3 months.	Barnacles less than *4. Algæ: *Rhizoctonia* and *Caloglossa*. Larvæ.	*Martesia* on top, scattered holes to $\frac{1}{8}''$ diameter, some dead. Larvæ of boring molluscs. *Sphæroma*, few in empty barnacle cases, no burrows.
*4, 6th September. 7 weeks.	Barnacles over 50% of surface. Mat of green algæ, diatoms, sponges. Protista, Molluscan larvæ, nemas and crustacean larvæ.	*Sphæroma*—1 colony in crack in wood, also Polychæte worm.
*3, 6th September. 4½ months.	Barnacles, heavy incrustation. Green algæ and small sponges, diatoms, etc. as *4.	*Sphæroma*, few half-grown animals in burrows on the base of block.
*6, 24th September. 5 months.	Barnacles scattered all over to $\frac{1}{2}''$ diameter, some empty. Green algæ, sparse, *Chætomorpha*; some blue green *Microcoleus*. Protista, sponges, Crustacean larvæ and young.	*Sphæroma*, numerous scattered burrows to $\frac{1}{4}''$ deep, in face ends and top of block. *Martesia*, few in face, $\frac{1}{4}$–$\frac{1}{3}''$ high. *Teredo*, numerous burrows in top and front in $\frac{3}{4}''$ saturated wood. Pallets variable. *T. diegensis* and *T. navalis*. Burrows 2–4″ long.
*1, 2 and 7, 30th November. 7 months.	Barnacles over all surfaces, some *Mitellus*, and Alga—*Chætomorpha*.	*Sphæroma*. few small burrows in each block.
TRAP II. MARUDU WOOD. WITH TRAP I. IMMERSED 24TH APRIL 1935.		
*4, 22nd May. 1 month (renewed).	As Trap I.	None found. Larva of boring Mollusc.
*4, 20th July. 2 months (renewed).	,,	None found.
*5, 20th July. 3 months.	,,	*Sphæroma*, few in empty barnacles. *Martesia*, few holes to $\frac{1}{8}''$ diameter, all dead, orifices 1′16″. Less infection than in Venteak.
*4, 6th September. 7 weeks.	,,	None found.
*3, 6th September. 4½ months.	,,	,,
*6, 24th September. 5 months.	,,	*Sphæroma*, *Martesia* and *Teredo*, all less than in Trap I. *Teredos* ½–1″ long, several dead. Few *Martesia* $\frac{1}{4}''$ high, mostly dead.
*1, 2 and 7, 30th November. 7 months.		*Sphæroma*, few burrows in Bl. 2, no borers in *1 and 7.

TRAP III. VENTEAK, AT PORT TRUST JETTY, NEAR HARBOUR ENTRANCE, COCHIN. IMMERSED 26TH APRIL 1935.

Block examined, date, and time immersed.	Surface growth.	Borers present.
*4, 22nd May, 1 month (renewed).	Barnacles, small, covering whole surface. Also many colonial hydroids, diatoms, nemas, protista, crustacean larvæ.	*Sphæroma*—2 small ones in empty barnacle case.
*4, 27th July. 2 months (renewed).	Barnacles covering whole surface; green algæ *Chætomorpha*, diatoms and crustacean larvæ.	None found.
*5, 27th July. 3 months.	Thick surface coating of barnacles, *Mitellus*, sponges, larval cases, few green algæ, with Crustacea and Planaria.	*Teredo*, several small burrows $\frac{1}{4}$—$\frac{1}{8}$″ long in base. *T. furcillatus* Miller, *T. navalis* L. and *T. samœnsis* Miller.
*4, 6th September. 6 weeks.	Covered in silt, very little growth. Few barnacles and green algæ, *Chætomorpha*.	*Sphæroma*, 3 small, in crack in block.
*3, 6th September. 4½ months.	Heavy growth of Barnacles and *Mitellus*; green and red algæ and silt. Crustacea and worms.	*Sphæroma*, 6 small, starting to burrow underneath. *Martesia*, 3 tiny specimens, burrows 1/16″ long. 1 dead.
*6, 25th September. 5 months.	Heavy, thick encrustation as *3, 6th September.	*Sphæroma*, few small in burrows.
*1, 2 and 7, 30th November. 7 months.	Barnacles over whole surface. Some algæ, *Chætomorpha* and *Caloglossa*.	*Sphæroma*, few burrows in 1/5″ deep in each block.
TRAP IV. MARUDU WOOD. WITH TRAP III. IMMERSED 26TH APRIL 1935.		
*4, 22nd May. 1 month (renewed).	As Trap III.	None found.
*4, 27th July. 2 months. (renewed).	,,	,,
*5, 27th July. 3 months.	,,	*Teredo*—few short burrows at ends $\frac{1}{8}$—$\frac{1}{4}$″ long. *T. navalis* L. *Sphæroma*, 1, in short burrow.
*4, 6th September. 6 weeks.	,,	None found.
*3, 6th September. 4½ months.	,,	*Sphæroma*, 5, in short burrows.
*6, 25th September. 5 months.	,,	None found.
*1, 2 and 7. 30th November. 7 months.	,,	*Sphæroma*, few burrows in Bl. 7, none in *1 and 2.

and *T. samœnsis* Miller. Professor R. C. Miller and other specialists have informed me that the taxonomy of this genus is still in a state of flux.

(4) *Bankia setacea* was not found in the traps. White[9] found specimens $\frac{1}{2}$″ long with typical pallets in wood after less than two months immersion in Departure Bay, British Columbia. He reports that in less than three months blocks of Douglas fir were so riddled with shipworms, that they could be broken by hand.

PROTECTION OF MARINE STRUCTURES AND WOODEN CRAFT.

Contrary to local opinion the activity of molluscan borers in Cochin harbour and vicinity is less than elsewhere. Wooden craft could certainly be protected indefinitely if they were taken into dry dock every two to three months, when the borers are tiny and close to the surface, and the keels scrubbed with a cheap poisonous wash, such as copper sulphate, mercuric bichloride, hot brine or lye solutions.

Fish oil and bitumen do not act as deterrents. They soften hard wood and seem to be attractive to Martesia.

Silt, sewage and a heavy incrustation with barnacles all tend to prevent the entrance of molluscan borers.

Sphæroma are always numerous and there seems to be not a way of protecting wooden piling except by sheathing them in copper or concrete.

SUMMARY.

Wood block traps were immersed at three stations in and near Cochin Harbour. They showed that the waters contain active larvæ of Martesia and Teredo from April to October. Owing to the low salinity growth of Teredo is very slow.

There are strains of Martesia and Balanus which can grow in almost fresh water.

According to pallet morphology four species of Teredo were found. Their attacks are limited to the region near the harbour mouth where the water is salt, and at levels at and near low water line.

Bankia setacea adults 19″ and 21″ long were found in wooden piles in the harbour, but no young appeared in the traps.

Sphæroma are always abundant and very destructive to piling.

Records of growth found in the traps for bi-monthly periods between April and November 1935 are given, also suggestions for the protection of wooden craft.

Centenaries in April 1936.

Grover (John William), 1836-1892.

JOHN WILLIAM GROVER, born on 20th April 1836, was an engineer with wide practice in several countries. He had his education first at Marlborough College and later in Germany. He was apprenticed under Sir Charles Fox and Sir John Fowler. His field of interest shifted from time to time. In the earlier years, he was engaged in Museum architecture and was associated with the building of the north and south courts of the South Kensington Museum and the erection of the conservatory of the Royal Horticultural Society. He also took a prominent part in the erection of buildings for the Exhibition of 1862. He was also associated with the erection of the Royal Albert Hall.

AS A RAILWAY ENGINEER.

In his 26th year, he set up independent practice as a Railway Engineer. His first work was the construction of 27 miles of the Manchester and Milford Railway. He surveyed various railways in Europe and prepared designs for the works of the Mexican Railway. The Kingland iron bridge, of 200 feet span over the Severn built by him, is said to present some novel features of construction. In 1873, he constructed the Mountain Railway of Venezuela. While at Venezuela he made a hydrographical survey of the coast of that country and thus prepared the way for the construction of the harbour of La Guaira.

AS A WATER-WORKS ENGINEER.

From his 37th year, he turned his attention to water-supply. He designed and constructed the water works of several towns in the Chalk districts. He was an authority on the water-supply of London. He was also employed in the survey of water-supply in Austria, Denmark, Egypt, Italy and Switzerland.

He was elected a member of the Institute of Civil Engineers in 1867 and was also a Fellow of the Society of Antiquaries and a Vice-President of the British Archæological Association.

Mr. Grover died at his residence in Clapham Common, on 23rd August, 1892.

HIS PATENTS AND PAPERS.

Of the patents taken out by Grover, the most widely known is the one for the "spring washer", used to prevent the slacking of permanent way fish bolts. These washers are being used in all parts of the world.

His chief papers are the following :—

1. "Estimates and Diagrams of Railway *Bridges*," *1866*. *2nd edition in 1870.* 2. "The Facilities of 'flexible' Rolling-Stock for economically constructing... Railways or Tramways," 1870. 3. "Description of a Wrought-iron Pier," 1871. 4. "Iron and Timber Railway Superstructures," 1874. 5. "Suez Canals from