The Story of the Oyster

Its History, Growth, Cultivation and Pests in New South Wales

By T. C. ROUGHLEY
Economic Zoologist
Technological Museum
Sydney

Reprinted from the Australian Museum Magazine, *Vol. II.* 1925

SYDNEY: ALFRED JAMES KENT, GOVERNMENT PRINTER.

84485—A

The Story of the Oyster

Its History, Growth, Cultivation and Pests in New South Wales

By T. C. ROUGHLEY
Economic Zoologist
Technological Museum
Sydney

Reprinted from the Australian Museum Magazine, *Vol. II*, 1925

SYDNEY: ALFRED JAMES KENT, GOVERNMENT PRINTER.

84485—A

PART I.

The Story of the Oyster.

THE oyster has an ancient and illustrious pedigree. Ancient no doubt it is, for it dates from a very old geological period; illustrious we must concede it to be, for it has provided a most palatable diet for man from the earliest records of his existence. Mounds of oyster shells or kitchen middens accumulated by man in the stone age are still to be seen in many parts of the world, and embedded in them are often found the primitive stone implements which were employed by these ancestors of ours to force open the shell.

There are no legible records of this remote age, and therefore the name of the first person who ate oysters is unknown. This is unfortunate. He is worthy of a monument "more lasting than brass."

The earliest account of the oyster we have in literature dates probably from the time of Aristotle, the Greek philosopher and naturalist, who lived from 384 to 322 B.C. Not satisfied with a superficial view of nature, Aristotle endeavoured to find out something about the internal structure of such animals as he was familiar with, and how they propagated their young. He concluded that oysters grew from mud by spontaneous generation. Now, the oyster has been blamed for many things in its time, but this reflection on its ancestry was sufficient to make it turn in its shell.

It is to the ancient Romans, however, that we owe most of our knowledge of the important part played by the oyster as an article of diet in these early times. Roman literature abounds with references to the oyster. Pliny the Elder (23-79 A.D.), for instance, gives us quite a lot of information about its virtues and the veneration in which it was held in the first century of the Christian era. Evidently following the lead of Aristotle, Pliny also informs us that it developed from mud, but added that the mud must be in a putrid state. He went even further, and stated that it also developed from foam that has collected round ships which have been lying for a long time in the same position, about posts driven into the earth, and more especially round logs of wood. A later and more careful observation convinced him that the oyster "discharges an impregnating liquid which has the appearance of milk." This, of course, is quite correct, and is the first accurate account in literature of any of the oyster's vital functions.

Oysters have at many times been credited with some remarkable virtues, not the least important being their rejuvenating effect on the human system, but in Pliny's eyes it was a regular panacea. "We will take the present opportunity," he says, "of stating all the medicinal properties that are attributed to oysters. They are singularly refreshing to the stomach, and tend to restore the appetite. Luxury, too, has imparted to them an additional coolness by burying them in snow, thus making a medley of the produce of the tops of the mountains and the bottom of the sea. Oysters are slightly laxative to the bowels; and boiled in honied wine, they relieve tenesmus in cases where it is unattended with ulceration. They act detergently also upon ulcerations of the bladder. Boiled in their shells, unopened just as they come to hand, oysters are marvellously efficacious for rheumatic defluxions. Calcined oyster shells, mixed with honey, allay affections of the uvula and of the tonsillary glands: they are similarly used for imposthumes of the parotid glands, inflamed tumours, and indurations of the mamillae. Applied with water, these ashes are good for ulcerations of the head, and impart plumpness to the skin in females. They are sprinkled, too, upon burns, and are highly esteemed as a dentifrice. Applied with vinegar, they are good for the removal of prurigo and pituitous eruptions. Beaten up in a raw state, they are curative of scrofula and of chilblains upon the feet."

A formidable array, indeed. What a fortune Pliny would have made if he had but lived at the present time!

Mound of oyster shells, commonly termed a kitchen midden, accumulated by the aborigines on the banks of the Richmond River, New South Wales.

[Photo.—*T. C. Roughley.*

The first century A.D. and a century or two previously have been referred to as the gastronomic age of ancient Rome. During this era the Romans were renowned for their sumptuous banquets, and enormous numbers of oysters were consumed, Pliny stating that the palm was awarded to them as a most exquisite dish. The consumption of immense numbers of oysters appears to have been regarded as an indication of refinement, as an accomplishment to be emulated at all costs, and the names of several persons who rather excelled in the noble art have been handed down to us. One, Aulus Vitellius, a Roman emperor (15-69 A.D.), whose feats of gluttony have probably never been surpassed before or since, is credited with having eaten one hundred dozen oysters at one sitting. Vitellius should be the patron saint of all oyster growers.

Cicero himself admitted that he had a special predilection for them, but tells us confidentially that he could renounce them without difficulty. Needless to say, posterity has not believed him.

The first person to form artificial oyster beds was Sergius Orata, who, about 195 B.C. established them at Baiae, on Lake Lucrinus, near Rome. Here he transplanted oysters which were collected from other parts of Italy and the Mediterranean, for in their new environment they were found to develop to a larger size and to acquire a flavour far surpassing that of the oysters grown in their original habitat. Orata's enterprise was rewarded by the accumulation of a large fortune.

In mediaeval times and up till about the sixties or seventies of last century, the oyster was held almost in reverence, and its virtues were extolled in the most extravagant language. Poems were written about it and odes were written to it. Listen to this: "The Oyster! The mere writing of the word creates sensations of succulence—gastronomical pleasures, nutritive food, easy digestion, palatable indulgence—then

Stone knives used by the Australian aborigines to cut the muscle of the oyster so that it might be removed from the shell.

[Photo.—*T. C. Roughley.*

go sleep in peace! . . . . . True, true oh oyster! Thou art the best beloved of the loved!"*

In Australia, the history of the oyster dates back a long way before the advent of Europeans, for it formed one of the principal articles of diet of the aborigines who inhabited these shores, and to this day are to be seen the huge mounds of shells left by them on the banks of many of the coastal streams. Probably the largest of these is to be seen on the north arm of the Richmond River. This mound extends for hundreds of yards, and is several feet in width and depth. Thousands of tons of shells have been used by the oyster cultivators to top-dress the mud flats which in their original condition were too soft to support the oysters it was desired to mature there. Large quantities have also been used to form the footpaths of Ballina. And still many thousands of tons remain. Fossicking amongst such heaps one frequently comes upon the stone implements used by the aborigines for cutting the muscles of the oysters when removing them from the shells. These primitive knives vary from three-quarters of an inch to two inches in length, and are fairly constant in shape. They were obtained by knocking smaller pieces off water-worn stones in such a way that at least one edge would be reasonably sharp.

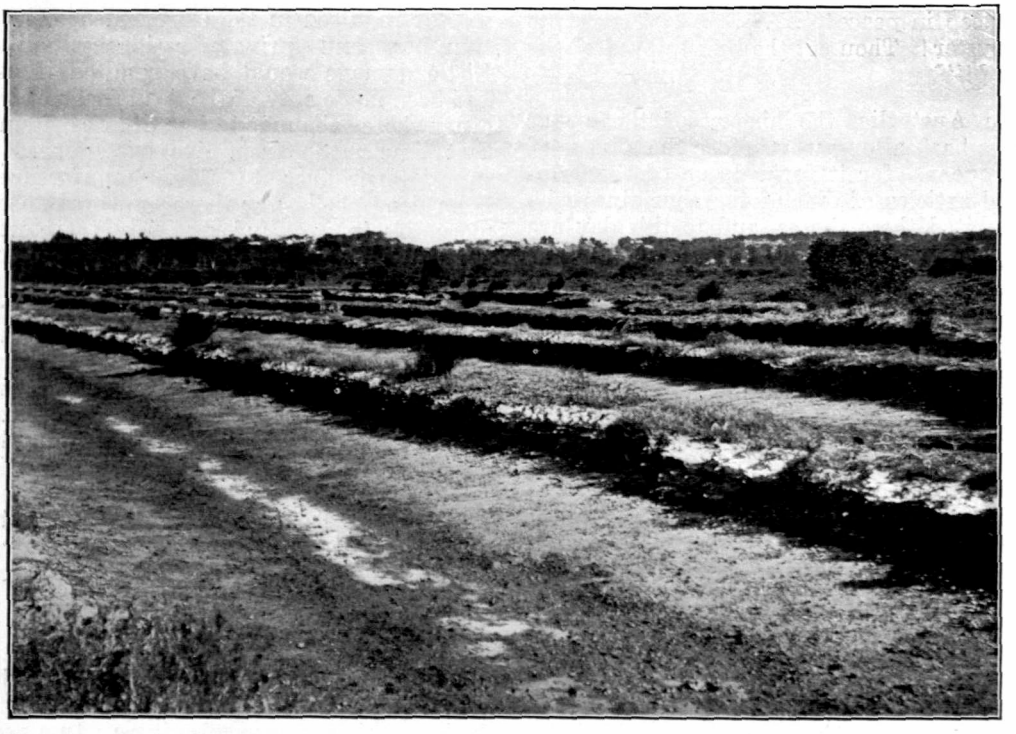
When our first colonists began to settle in the coastal districts, oysters were found in most of the estuaries in extreme abundance. The supply appeared to be inexhaustible. But the shells, which are rich in lime, were requisitioned for use in the mortar required in the Government offices, churches, and private residences alike. Little damage would have resulted if use had been made only of the dead shells which everywhere abounded, but it was found that lime made from live oysters was a superior product to that manufactured from dead shells, for there appeared to be more life in it. Unfortunately there was more body in it also. It was customary to stipulate in contracts that the lime to be used must be the product of live oysters. As settlement progressed the demand for oyster shell lime grew apace, and it requires little effort of imagination to conjure up the enormous havoc played on the natural beds by the limeburners. As the population increased, so, in proportion, did the demand for oysters for edible purposes, until at last the inevitable happened—the supply was insufficient to meet the requirements, and legislative action was rendered necessary in 1868 prohibiting, under a heavy penalty, the burning of live oysters for lime.

Having depleted the natural supply, the men engaged in the trade were forced to devise artificial means of culture. In a new project such as this, it was but natural that the first attempts at cultivation should closely follow the lines of those methods which had proved successful in other countries.

The Hon. Thomas Holt, a member of the New South Wales Legislature, had, about this time, visited France, the home of oyster culture, and had studied the various systems adopted there. Consequently, on his return about 1870, he constructed channels, or "claires," as they were termed in France, on the banks of Gwawley Bay, George's River, after the most approved French fashion. These channels, when

* "The Oyster: Where, how and when to find, breed, cook and eat it." Anon 1861.

completed, aggregated some thirty miles in length, were twenty-two feet wide, and of sufficient depth to retain from two to four feet of water at low tide. The inlet and outflow of water were regulated by means of flood-gates and dams exactly as had proved so eminently successful in France. Upwards of two hundred men were employed and many thousands of pounds expended in their construction. They were stocked with oysters obtained from Port Hacking, Cowan, Brisbane Water, and Pittwater. For a number of reasons they were a failure. Holt had reckoned without the heat of the Australian sun, which raised the temperature of the still water to a degree which the oysters could not withstand, and large quantities were also smothered by depositions of silt. After a trial extending over a period of two or three years the whole project was abandoned.

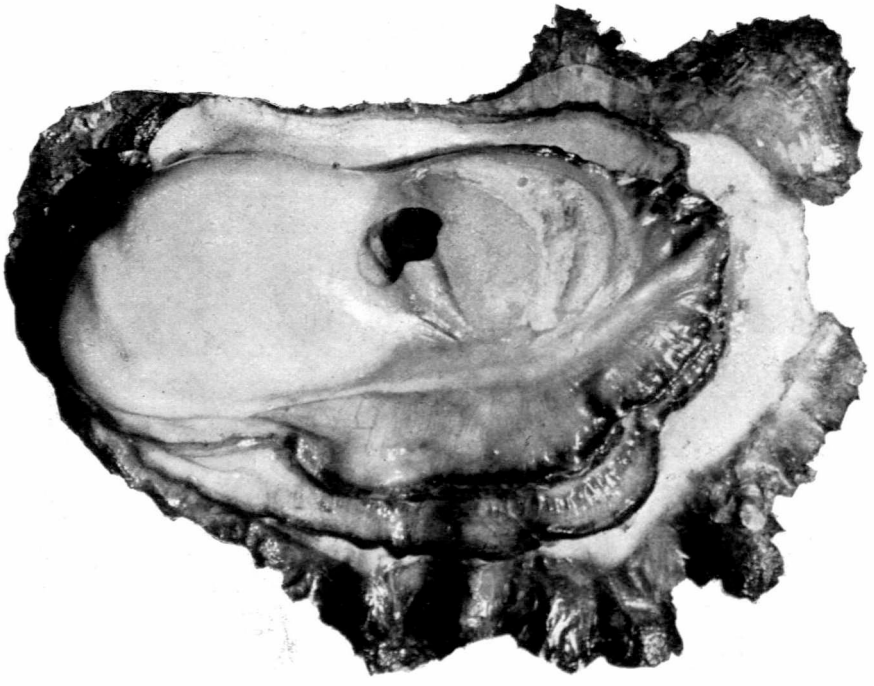


Present day view of channels, or "claires," constructed on the shores of Gwawley Bay, George's River, to mature oysters obtained from Port Hacking, Cowan, and elsewhere. Great hopes of these were entertained, but, unfortunately, were not justified.

[Photo.—*T. C. Roughley.*

For a considerable time after this experiment, oyster growers exhibited an entire lack of enterprise, little more being done than the transplanting of oysters from localities where growth was slow to more favourable situations where development was more rapid, until 1896, when organised systematic cultivation may be said to have begun. Oyster farmers now began to lay out sticks, stones, and shells to catch spat and support it till it developed to maturity. The areas under cultivation were increased yearly, new methods were evolved, and a higher degree of efficiency attained as the lessees began to acquire a better knowledge of the peculiarities of their product, until gradually the industry developed into the extensive one it is to-day. The various methods of cultivation in vogue on the coast of New South Wales at the present time will be described in a later issue of this MAGAZINE.

There are several species of oysters found on the Australian coast, but only two are of commercial value, the rock oyster (*Ostrea*

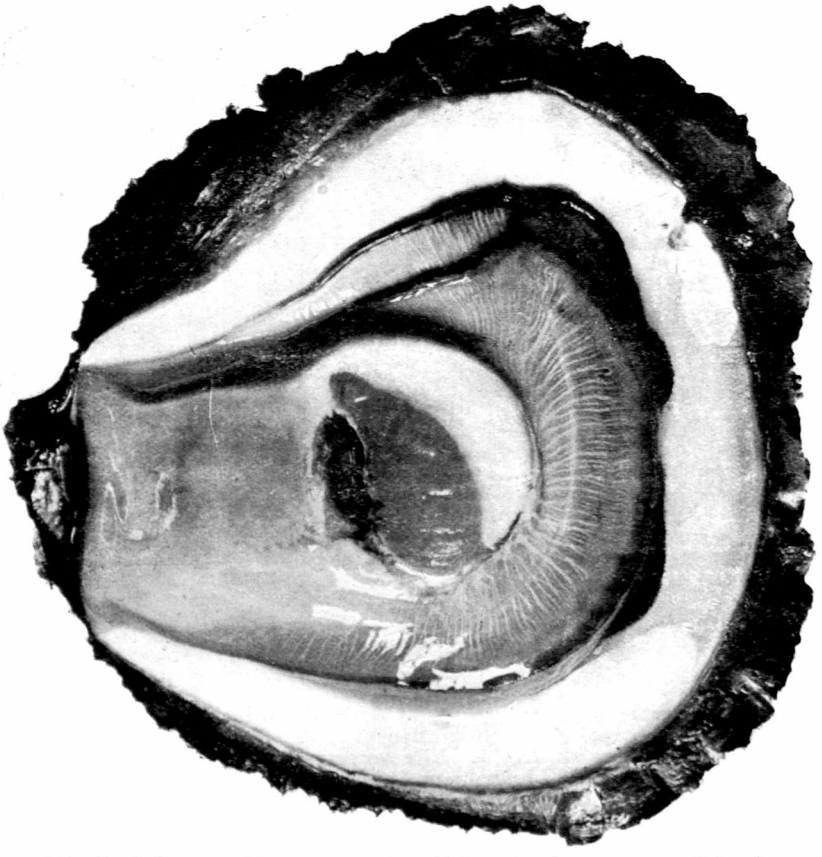


The Rock Oyster (Ostrea cucullata). This, the principal Australian oyster of commerce, although smaller than the Mud Oyster, is far superior in delicacy of flavour. The average weight is about 2 oz., but one example weighed half a pound and measured 6 x 4 x 2 inches. The illustration is slightly above the natural size.

[Photo.—*T. C. Roughley.*

cucullata), and the so-called mud oyster (*Ostrea angasi*). Of these, the rock oyster is far and away the more important, not only on account of its greater abundance and wider distribution, but also because of its superior edible and keeping qualities. On the west coast of Australia it is found as far south as the 30th parallel of south latitude (about 150 miles north of Perth), and extends right round the northern, eastern, and south-eastern seaboard as far as Gippsland Lakes in Victoria, where, however, it is not common. On the south coast of Australia it does not occur at all. It thrives best between the Tropic of Capricorn (Rockhampton) on the north and the border between New South Wales and Victoria on the south. North of Rockhampton it is quite prolific, but, owing to the great rise and fall of the tide, and the heat of the tropical sun, the shell remains stunted and crinkled, and therefore the oyster is of little commercial value. The main fishery for the rock oyster is carried on in New South Wales and to a less extent in Queensland. It has a wide range outside Australian waters, being found in India and also in Japan, where it has been cultivated by means of bamboos for a very long time. It occurs also on the North Island of New Zealand, but in much smaller quantities than on the Australian coast.

The habitat of the mud oyster extends from the Leeuwin along the whole of the south coast, and on the east coast as far north as the Clyde River in New South Wales, where it is now scarce. In the early days of the colony the mud oyster was found on all the rivers south of and including the Clarence, but at the present time it is extinct north of the Clyde, although large quantities of shells are still to be found. It thrives best at Port Lincoln near Adelaide, and for this reason is sometimes known as the Port Lincoln oyster. No mud oysters are marketed in New South Wales, but considerable quantities find their way to the Melbourne and Adelaide markets.



The Mud Oyster (Ostrea angasi). Although of no commercial value in New South Wales, considerable quantities are marketed in Victoria and South Australia. The illustration is a little less than natural size, but one specimen measured 9 x 5½ x 2½ inches and weighed 2 lb.

[Photo.—*T. C. Roughley.*

where it brings only from one-third to one-half the price of the rock oyster, which is imported in large quantities from New South Wales and Queensland. From here, also, considerable numbers are exported to Western Australia, particularly during the winter months.

The term "mud oyster" is really a misnomer, for it cannot live when completely submerged in mud. No true oyster can. When it has completed its development as a free-swimming larva, it must fasten its shell to some object in the water or perish, but, whereas the rock oyster will continue to grow along the surface for a very considerable time afterwards, forming a large and secure area of attachment, the mud oyster soon grows out from its base, which is therefore relatively small. Owing to its large size, it usually becomes detached and falls to the bottom. Should the bottom happen to be firm the oyster will continue to live and thrive, but if it should drop into soft mud it soon becomes smothered.

Another characteristic difference between the two species is that the rock oyster lives and flourishes both between tide marks and below low tide to very considerable depths, while the mud oyster is rarely, if ever, found above low-tide level. Then, too, as regards their keeping qualities, the rock oyster will live out of water for upwards of two weeks in summer and three weeks in winter. The mud oyster, however, usually succumbs in a few days after removal. Moreover, for delicacy of flavour the Australian rock oyster is probably unsurpassed by any oyster found elsewhere in the world.

PART II.

The Birth and Growth of an Oyster.

WHAT is an oyster? You will probably answer that it is a delicious mouthful, barricaded by a stony wall that is very difficult to breach. But how many of you have ever stopped to consider what it is composed of? Most people have a hazy notion that it is an animal of some sort, but few have any idea of how it a mass it may appear to be, it must feed and breathe, for it cannot otherwise live. The purpose of this article is to show that the oyster has quite an elaborate anatomy, and that the account of its growth from a tiny egg, too small to be seen with the naked eye, is a fascinating story of Nature's wonderful handiwork.

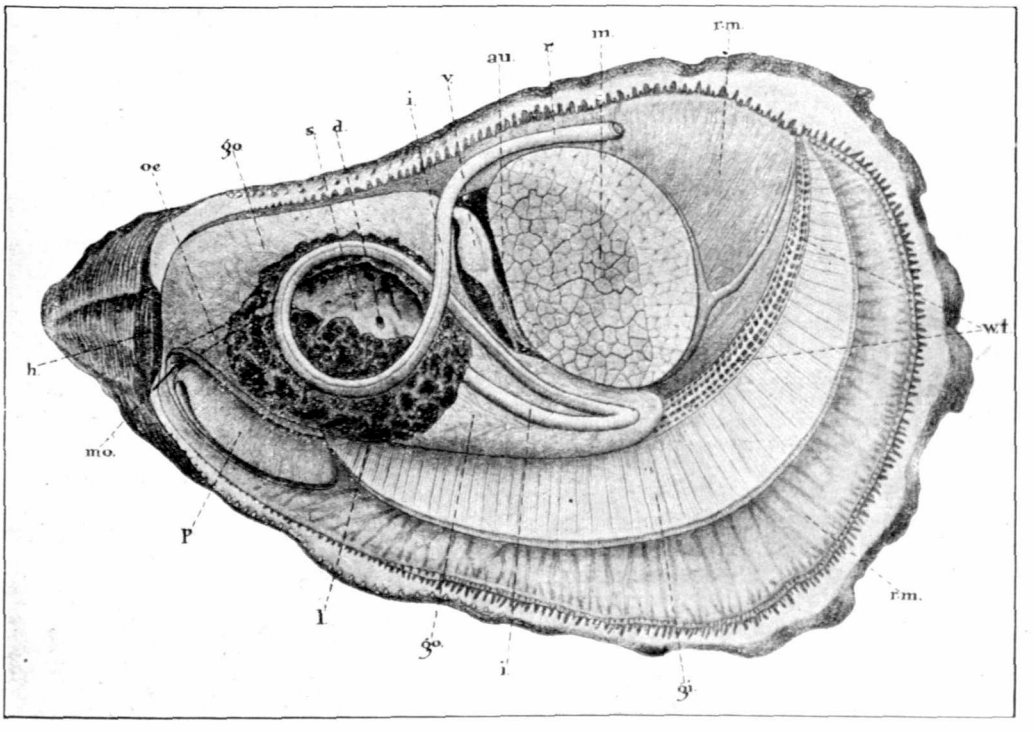


Fig. 1.—Diagram of an oyster, dissected to show its principal organs. The whole of the left mantle and the uppermost palp have been cut away in order to expose the gills and the mouth respectively.

oe. oesophagus; *go.* gonad; *s.* stomach; *d.* duct from liver; *i.* intestine; *v.* ventricle; *au.* auricles; *r.* rectum; *m.* muscle; *r.m.* right mantle; *w.t.* water tubes. *gi.* gills; *l.* liver; *p.* labial palps; *mo.* mouth; *h.* hinge.

[*T. C. Roughley*, del.

lives; whether it has organs in any way similar to those possessed by higher animals, and whether it feeds and breeds in a manner comparable, for instance, to what we find in fishes. Of course, no matter how small an animal is, no matter how shapeless

Let us first examine the shell. This is composed of two parts or valves, the upper valve being flat and the lower one more or less deeply concave, forming a cup-shaped bed in which the oyster lies. These valves are joined together at the front or anterior

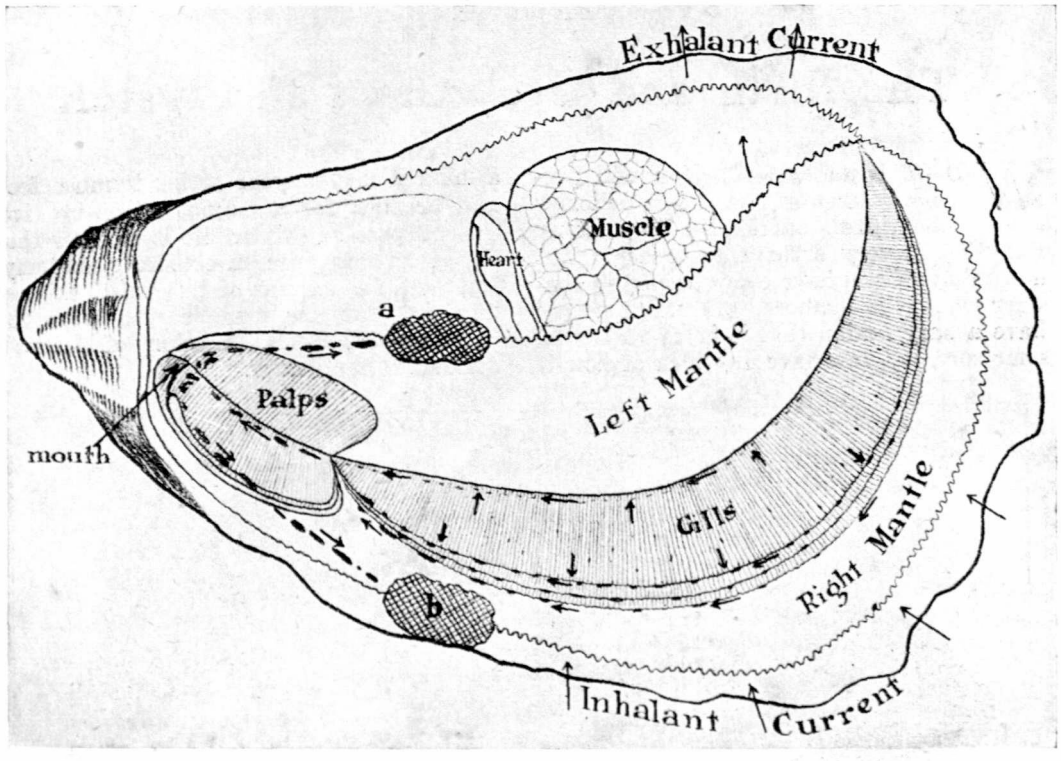


Fig. 2.—Diagram of an oyster to show the course taken by the food. The left mantle and the uppermost palp have been folded back in order to expose the gills and underlying palps. Normally the edges of the mantles are in close apposition, and the two accumulations of rejected material a and b are a common mass.

[*T. C. Roughley*, del.

end by an elastic ligament which has a tendency to open them. Each shell is composed of three layers, an outer one of horny consisteney, a middle one, somewhat chalky, composed of prisms of carbonate of lime, and an inner pearly or nacreous layer, which is smooth and hard, and more or less iridescent. Although the exterior is rough and often misshapen, a careful examination of the interior reveals that the shells are really masterpieces of an unerring craftsman. They fit together so accurately when closed that not a drop of water will leak through them. When it is considered that they often grow on objects of most irregular shape, and must follow each irregularity, the consummate skill of the animal becomes at once apparent. Man, under similar circumstances, would require a pad of rubber or leather to keep the chamber watertight.

Having opened the oyster by forcing a knife into the edge farthest from the hinge and cutting the muscle close to the deep shell, we find that the oyster lifts out attached to the flat or right shell, so that we are therefore looking at the left side. It appears on the surface to consist of four different parts—(1) a relatively firm muscle (fig. 1, *m*) which when contracted serves to close the shells; (2) a white mass, the reproductive gland (*go*) between the muscle and the hinge (*h*); (3) a smaller oval area, the pericardium somewhat darker in colour, lying between the muscle and this white mass; and (4) the mantle, frequently known as the "beard," hanging freely from the body of the oyster. The mantle consists of two thin leaf-like folds that lie against the inner sides of the shell, fitting round the more compact parts of the body much the same as a man's coat fits

over his body, but with this difference—it is firmly adherent along the sides and is a real part of the living animal. The edge of the mantle is provided with tentacles, and can be protruded beyond the shell, but in opened oysters it is withdrawn well within the margin. The principal functions of the mantle are to protect the organs that lie beneath it, and to secrete the shell. The outer and middle layers of the shell are secreted by the edge of the mantle, and the inner pearly layer by the whole of its surface.

The reproductive gland produces the elements, eggs or sperms as the case may be, by means of which the young oysters are propagated. When this gland is large and swollen the oyster is said to be fat or in good condition.

The muscle is a powerful organ which serves to close the shells. When it relaxes, the elasticity of the hinge ligament forces the shells apart, so that, when an oyster dies and the muscle is no longer capable of functioning, the shells usually gape.

The pericardium is covered by a thin-walled extension of the mantle, upon the removal of which the heart is disclosed. This consists of two auricles (*au*) and a ventricle (*v*); the former receive the blood from the gills and by contracting force it into the single ventricle, which in turn pumps it into the aorta, whence it is conveyed through many channels to the various organs of the body. The blood is quite colourless and contains innumerable blood cells capable of movement in a manner exactly similar to amoebae, those most primitive of all forms of animal life. The heart may beat for some hours after the oyster has been opened, and, if the oyster is put back into the water, it may continue to beat for several days. The pulsations are regular and vary with the temperature.

If the mantle is lifted up, two different sets of organs are exposed to view: the first, situated near the hinge, consists of four leaf-like folds, the labial palps or lips (*p*); the second, long and sickle-shaped, extends from the lips to the distal extremity of the body behind the muscle. This also is a four-fold organ and constitutes the gills (*gi*), which serve the double function of aerating the blood and procuring the food. Each gill leaf is covered by myriads of microscopic hairs, or cilia, which vigorously vibrate in such a way that a continuous stream of water is drawn towards them when the valves of the shell are open. The water passes into minute holes in the surface and is conducted upwards through water tubes (*w.t.*) in the interior to be expelled through the apertures along the upper edge. From here it enters a space known as the supra-branchial chamber and leaves the shell above and behind the muscle. As the water passes through the gills the blood is aerated in much the same manner as the blood of a fish, but the gills of the oyster serve also to strain the water. All matter in suspension is collected by the cilia and passed up or down towards the edges, along which it is conducted forward to the bases of the palps (fig. 2). The latter, also covered with cilia, pass this matter forward towards the mouth. The palps sort out the food from the waste matter, the former being drawn into the mouth, the latter being conveyed back along their outer margins, and over a well defined track to the edge of the mantle. When a sufficient amount of rejected material has accumulated, the oyster snaps the shells and ejects it. The food of the oyster consists for the most part of microscopic vegetable life, composed principally of diatoms and other unicellular algae, which abound in salt water practically everywhere.

After entering the mouth (fig. 1, *mo*), the food is conducted along a narrow tube known as the oesophagus or gullet (*oe*), which opens into an irregular cavity, the stomach (*s*). Surrounding the stomach on all sides, and completely enclosed by the reproductive gland when the latter is well developed, is a dark brown organ known as the digestive gland or liver (*l*). This continually pours a secretion into the stomach through several branching channels (*d*), and by means of this fluid the food is digested. Leaving the posterior extremity of the stomach, the food passes into the long and narrow intestine (*i*), which runs downwards and backwards into the projection of the body lying beneath the muscle; here it turns forward and coils round the stomach, finally as the rectum (*r*) passing over the pericardium and muscle, above which it terminates.

The oyster has a primitive though adequate nervous supply, consisting of two main nerve centres, or ganglia, and many branching nerves. It has also paired kidneys situated one on each side below the muscle.

What appeared at first sight to be a shapeless unorganised mass has now, with a little careful dissection, disclosed a highly specialised anatomical structure, capable of performing such intricate and involved functions as breathing, feeding, digestion, blood circulation, and excretion. So you see the oyster is something more than a mere mouthful of deliciousness.

Vital to an oyster's existence as are all the foregoing functions, the propagation of its young is no less vital to the continuance of the race, but before relating the romantic side of an oyster's life, it must be clearly understood which oyster is being described. There are two species of oysters of commercial importance in Australian waters, the rock oyster (*Ostrea cucullata*), and the so-called mud oyster (*O. angasi*). The life histories of these species differ in several well-marked particulars, and it will be necessary therefore to treat each separately. The more important rock oyster will be considered first. In this species the sexes are separate, i.e., each oyster is either a male or a female, and remains so throughout life. Now, as the oyster grows, the reproductive gland becomes a much swollen organ, and gradually comes to assume relatively enormous proportions. In the female it is actively developing eggs or ova, and in the male sperms. When the oyster is sexually mature, these eggs or sperms are extruded from the reproductive gland through two openings, the gonaducts, situated one on each side of the body directly beneath the muscle. When this process takes place an oyster is said to spawn.

The matter expelled from the reproductive gland appears to the naked eye to be a white fluid resembling milk. When examined under the microscope, however, the fluid from the female is seen to consist of an enormous number of eggs which vary considerably in shape (fig. 3); they may be rounded, oval, or more commonly pear-shaped, and measure approximately $\frac{1}{500}$ of an inch. Several million eggs may be ejected from a female oyster in one

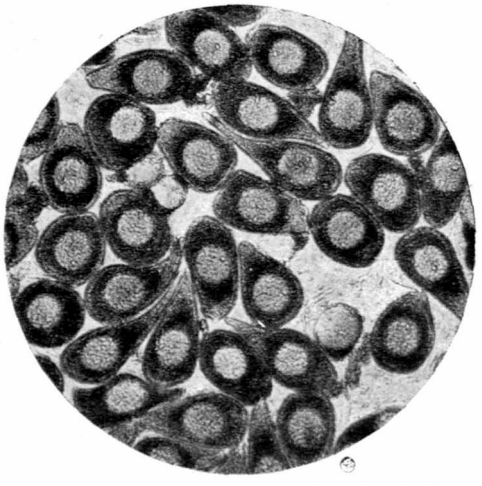


Fig. 3.—Ripe eggs or ova of a Rock Oyster (Ostrea cucullata), 1-500th of an inch in width. Magnified 150 times.

[Photomicrograph—*T. C. Roughley.*

spawning season, which usually occurs during late summer. The liquid from the male is seen to consist of extremely small actively swimming organisms known as sperms or spermatozoa. These are composed of a minute head and a long, flexible tail, which enables them to swim very vigorously. Small though the eggs are, the spermatozoa are very much smaller, and it would take several thousands to make up the bulk of an egg. Thousands of millions of them may be ejected from one oyster during a single spawning period.

As the milky liquid accumulates inside the shells, the parent oyster at frequent intervals sharply snaps the shells together, and throws it out in the form of a white cloud. Once in the water the spermatozoa dart in all directions in search of eggs, and when one spermatozoon has effected an entrance inside an egg, fertilisation is said to take place, after which no more can enter. If an egg remains unfertilised it cannot further develop. Very soon after fertilisation marked changes take place within the egg; it quickly divides into two unequal parts, the smaller half again dividing into two, and so on till, in a short time, the single original egg has changed to a globular mass of very much smaller cells. While these changes are taking place there is no increase in size, but, in the course of

a few hours, minute hairs develop at one end, and by means of their active vibration, the embryo, as it is now called, begins to swim about. Although under the microscope it appears to travel at a wonderfully fast rate for its size, its movements on a scale comparable with surrounding objects are very feeble. It cannot swim against a current, but is carried about at the mercy of wind and wave. After a day or two as a small, naked cluster of cells, shells begin to form on each side and rapidly grow downwards till they completely cover the body, when they can be opened or closed at will. At this stage the hinge uniting the shells is a straight one. Portion of the body can be protruded beyond the rim and by means of hairs or cilia propel the embryo. Oyster embryos can be raised to this stage by means of artificial fertilisation, *i.e.*, the mixing of spermatozoa from a male with eggs from a female in a vessel containing sea water, but when the shells develop the embryo begins to feed, and no practical method has yet been devised to supply the food, some idea of the size of which can be gathered when it is remembered that the whole animal is still little more than $\frac{1}{800}$ of an inch long.

From the time of the fertilisation of the egg till the shells envelop it, the developing oyster is called an embryo, from the early shelled stage till it attaches itself to an object it is known as a larva, and after attachment as a spat. From the early straight hinge stage growth is rapid, the shell daily increasing in size and the organs of the body becoming more specialised. When the larva is about half-grown and is about $\frac{1}{180}$ of an inch wide, a marked change begins to take place in the shape of the shells. They begin to grow upwards on each side of the hinge, the growth of the left shell being considerably greater than that of the right one, so that when seen lying on the left side, the projection of the left shell appears as a well-defined prominence. The inequality of these outgrowths of the shells, or umbos as they are called (fig. 4, *u*), serves to distinguish oyster larvae from those of other bivalves, which, in the earlier stages of growth, they resemble to a remarkable degree. With the advent of the umbos there appears another organ peculiar to this period of an oyster's development; this is known as a foot (*f*), and by its means the larva is enabled to crawl about. The foot can be extended for a distance approximately equal to the width of the shell, becoming narrower as it protrudes. It is covered with cilia, strongest at the tip, and by attaching the extremity to an object and then suddenly contracting, the shell is dragged after it. By repeating this movement the larva can crawl quite considerable distances, and extricate itself from mud and other debris which might for the time being imperil its further existence.

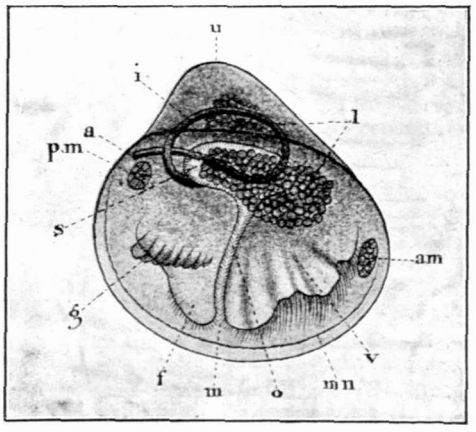


Fig. 4.—An oyster larva, 1-90th of an inch wide, showing its principal organs. Magnified 140 times.

m. mouth ; *f.* foot ; *g.* gills ; *s.* stomach ; *p.m.* posterior muscle ; *a.* anus ; *i.* intestine ; *u.* umbo ; *l.* liver ; *a.m.* anterior muscle ; *v.* velum ; *mn.* mantle ; *o.* oesophagus.

[*T. C. Roughley*, del.

Reference to figure 4, which is an enlarged drawing of an oyster larva $\frac{1}{90}$ of an inch wide, will show that it already has a highly specialised set of organs. The swimming organ or velum (*v*) provided at its edge with very strong cilia, can be protruded and opened out somewhat after the manner of an umbrella (figs. 5 and 6), and the rapid vibration of the cilia enables it to swim about at will. The foot (fig. 4, *f*) is already fairly well developed, and lying in close apposition to it are the rudimentary gills (*g*). Between the velum and the foot is situated the mouth (*m*), which leads into a long and narrow oesophagus (*o*), a ciliated channel that serves to conduct the food into the stomach (*s*). This, too, is lined with actively vibrating cilia which

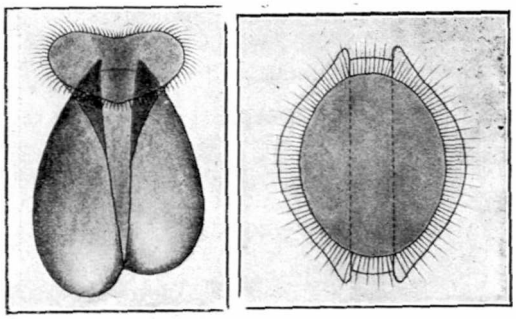


Fig. 5.—Oyster larva with velum or swimming organ partially extended. Magnified 110 times.

Fig. 6.—Oyster larva with swimming organ (shaded) fully extended. Magnified 110 times.

[*T. C. Roughley*, del.

serve to keep the food in a constant circular motion, while the digestive juices from the liver (*l*) convert it into a form suitable for assimilation. The intestine (*i*), after leaving the stomach, coils over on itself and terminates as the rectum above the posterior adductor muscle (*p.m*). During its larval life the oyster is provided with two muscles, an interior (*a.m.*) and a posterior (*p.m.*), but soon after it is fully grown and attaches itself to an object in the water, the anterior muscle is absorbed, and the posterior muscle develops into the large adductor muscle of the adult oyster.

It will be seen that the most prominent organs possessed by the oyster in its later larval life are the velum or swimming organ, and the foot which enables it to crawl about. This is, of course, to be expected in an organism in which locomotion plays so important a part, but having completed its free swimming existence it begins to search about for a clean surface where it may attach its shell and take up its permanent abode. Should no such surface present itself within two or three days after larval development is complete, it mush perish. If it is fortunate enough to encounter a stone, shell, or stick, for instance, it immediately cements its deeper left shell to it, and there it remains for the rest of its life, or until some ruthless oyster cultivator knocks it off for market. Having now become definitely and indissolubly fixed, it has no further use for the swimming organ and foot, which therefore quickly degenerate and are absorbed.

The size of a newly attached oyster, known to oyster growers as a spat, averages about $\frac{1}{15}$ of an inch in length, and it is asymmetrical, the left shell being larger than the right and projecting above the hinge (fig. 7). Immediately after attachment the spat shell grows rapidly, and is in close contact with the surface on which it lies. After about twelve months the edge of the shell furthest from the hinge begins to grow upwards and away from the surface, and the depth of the oyster to increase largely.

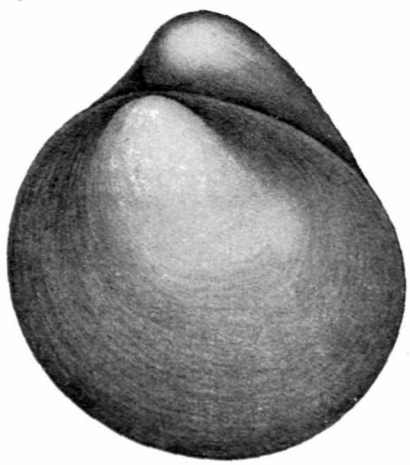


Fig. 7.—A Rock Oyster spat, 1-75th of an inch long, immediately after it has attached its shell to an object in the water. Note the prominence (umbo) of the lower left shell. Magnified 175 times.

[*T. C. Roughley*, del.

The length of time that elapses between the fertilisation of the egg and the attachment of the subsequent spat has not been determined in Australian waters, but about New Jersey, in the United States of America, where the summer temperature of the water is frequently similar to that which prevails in New South Wales, the time taken is approximately a fortnight. It takes, on an average, three years for an oyster to grow to a good marketable specimen, though under favourable conditions of food, temperature, and salinity it may reach that size in two years.

Now it must be clearly understood that the life history just described refers to the rock oyster, which differs in several important particu'ars from that of the mud

Fig. 8.—Mud Oyster (Ostrea angasi). The left mantle (m) has been turned back to show the mass of developing larvae (l). Two-thirds natural size.

[Photo.—*T. C. Roughley.*

oyster. The latter is hermaphrodite, or in other words each oyster is both a male and a female, though it cannot fertilise its own eggs, and does not function as a male and a female at the same time; it may, however, function as a male and eject sperms early in the summer and develop eggs later in the same season. Unlike the rock oyster, the eggs are not fertilised in the water, but after leaving the gonaduct of the parent are retained between the mantles, where sperms from other oysters, drawn in with the current of water, effect fertilisation. About half the larval life is passed here under parental supervision, during which time the larvae develop shells, and in the mass appear to resemble extremely minute sand grains, at first light in colour, but later changing to a dark grey (fig. 8, *l*). When ready to be ejected these shelled larvae have a straight hinge and a well developed set of organs, and measure about $\frac{1}{180}$ of an inch long (fig. 9). Having been cast into the water they at once begin to swim about in search of food. From then onwards development is precisely the same as is that of the larva of the rock oyster at similar stages of growth.

This method of development is not peculiar to the Australian mud oyster, but is common also to the commercial oyster of England and France (*Ostrea edulis*). You have no doubt heard that oysters should not be eaten during the months of May, June, July, and August, those months, in other words, which do not contain the letter "r." This obtains with the English oyster, for during those months the oysters spawn,

and a percentage of them will be found with developing young in the mantle cavity of the parent. These, being enclosed in shells, would feel like fine grit in the mouth, and therefore are undesirable gastronomically, but it must also be remembered that there are upwards of a million larvae in each oyster; each of these is a potential adult, and for the conservation of the supply it is vitally necessary that it should have an opportunity of developing, which would be lost if the parent were removed from the water. For these reasons, therefore, oysters are not eaten in England during the months which normally constitute the breeding season.

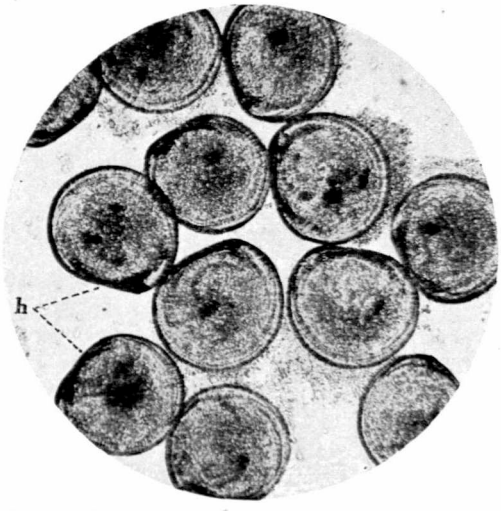


Fig. 9.—Mud Oyster larvae, 1-150th of an inch wide, extracted from the mass shown in Fig. 8 (l). Magnified 100 times. (h) Hinge.

[Photomicrograph—*T. C. Roughley*

Australian rock oysters may be eaten freely during all months of the year. They are of finest flavour previous to spawning, when the reproductive gland is well developed. If the spawning has been a heavy one, or, in other words, if the whole of the sexual elements have been ejected, the oyster becomes thin and unpalatable. Fortunately oysters in different rivers on the coast of New South Wales spawn very irregularly, and the market can usually be kept supplied with oysters in good condition throughout the whole of the year.

PART III.

The Cultivation of the Oyster.

THE casual observer in his wanderings along the foreshores of our rivers and estuaries, noticing an abundance of oysters attached to the rocks or mangroves, probably imagines that oysters, like the proverbial and obliging "Topsy," just grow, and require only to be gathered and sent to market. The percentage of such naturally grown oysters that are marketed in New South Wales is a very small one, the great bulk being cultivated by artificial means, oftentimes with as much care as an orchardist gives to his fruit or a farmer to his wheat.

Stone heaped into long rows to catch the young oysters or spat, as they are termed. When from 12 to 18 months old the oysters are knocked off and laid on level beds topdressed with shells or gravel. Brunswick River, New South Wales.

[Photo.—*T. C. Roughley.*

For about a century after the colonisation of Australia began, the natural crops of oysters were sufficient to meet the requirements of the market, not only for edible purposes, but also for conversion into lime. Oyster beds were depleted without thought of the morrow, and in the 'seventies and 'eighties of last century the available supply of naturally grown oysters failed to meet the demand. Means had then to be devised to bring the supply up to normal requirements, and artificial culture had to be resorted to. By the artificial culture of oysters is meant the laying out of suitable material in positions where the free-swimming oyster larvae abound in order that they may have an opportunity of attaching themselves, and the transference of these attached larvae, or spat, as they are then called, to a faster growing ground if the one where they were caught is not conducive to rapid growth.

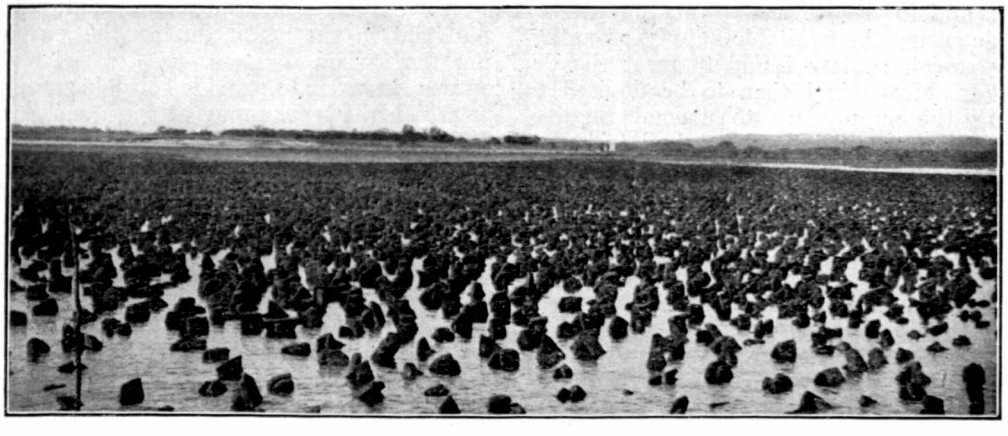
We have seen in the last issue of the AUSTRALIAN MUSEUM MAGAZINE that in its early life the oyster leads a free-swimming existence, later developing a foot which enables it to crawl about, and that, if a reasonably clean surface is not encountered within a couple of days after the complete development of the larva, it must perish. The object of the oyster cultivator is to place material in the water during the summer months, when oysters are expected to spawn, in order to provide suitable surfaces to which the larvae may attach themselves. Indications of areas where oyster larvae abound are usually given by the abundance of the catch on rocks and mangroves in the vicinity. The best spat-catching grounds are generally found at or near the mouths of rivers where the water is clear and the salinity fairly high, for not only do the larvae thrive best under such conditions, but the material placed in the water remains comparatively clean. Such situations are not favourable to quick growth, the best maturing grounds being found where the water is more brackish upstream. The ideal method of cultivation, therefore, is one which allows the material to be placed in

the clearer water to catch an abundance of spat, and later to be transferred to more brackish water where food is plentiful and growth is rapid.

The commercial oyster of New South Wales (*Ostrea cucullata*) grows and thrives both between tide levels and when submerged in water down to depths of fifty feet or more. Cultivation varies according to the locality of occurrence, which may be a long narrow foreshore, an extensive mud flat, or a firm, shelly, gravelly or shingly bottom never bared by the tide.

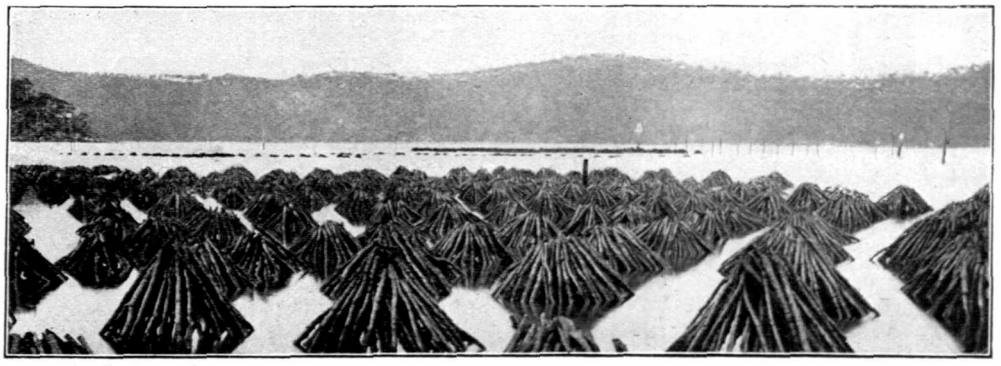
The essential requirements of material used to catch and rear oysters are (1) the surface must be reasonably smooth and firm; (2) it should last for at least three years in the water without decay; (3) it should allow the oysters to be detached without breaking their shells. The material which satisfies these demands most adequately is sandstone, which cleaves easily, lasts indefinitely, and readily parts with the oysters. The foreshores of several of our rivers are abundantly supplied with sandstone, but there are many on the north and south coasts where it does not occur. On some of these a shale or slate is used, while on others the stone is so hard that a large proportion of the oysters which attach to it is broken when an effort is made to remove them. On such rivers the sandstone ballast which in the early days was dumped over from sailing vessels has been conserved and the utmost use made of it, but the bulk of the cultivation has to be done by means of other materials. Of these, sticks of various kinds have of recent years come largely into vogue. The trees used are very limited in number for the reason that all but a few are subject to such rapid decay, due to the ravages of boring marine animals such as "cobra" (*Teredo*), that they fall to pieces before the oysters are mature. The best stick is that obtained from the Black or Red Mangrove (*Aegiceras majus*), which not only lasts well in the water when used in even very small dimensions, but which has a smooth bark capable of being readily detached from the wood when it is necessary to remove the oysters. To a less degree Swamp Oak (*Casuarina glauca*), and White Honeysuckle (*Banksia integrifolia*) sticks are also used; these last well, but the surface of the bark is rougher than that of the Black Mangrove, and rarely catches the quantity of spat secured by the latter.

Cultivation in New South Wales is about equally divided between stones and sticks. Stones possess the advantage of permanency, but sticks, owing to their ease of transportation in large numbers, are more efficient for intensive cultivation; they may be laid down in great numbers on a good spat-catching ground and removed, thousands at a time, to a good maturing ground. In this way the greatest numbers of oysters are grown most rapidly.



Sandstone slabs laid in pairs like an inverted "V." The spat that is caught on these stones is allowed to remain attached until it matures into marketable oysters. Pelican Point, George's River, New South Wales.

[Photo.—*T. C. Roughley.*



Sticks of the Black Mangrove (Aegiceras majus) clustered together in order to catch the spat. Hawkesbury River, New South Wales.

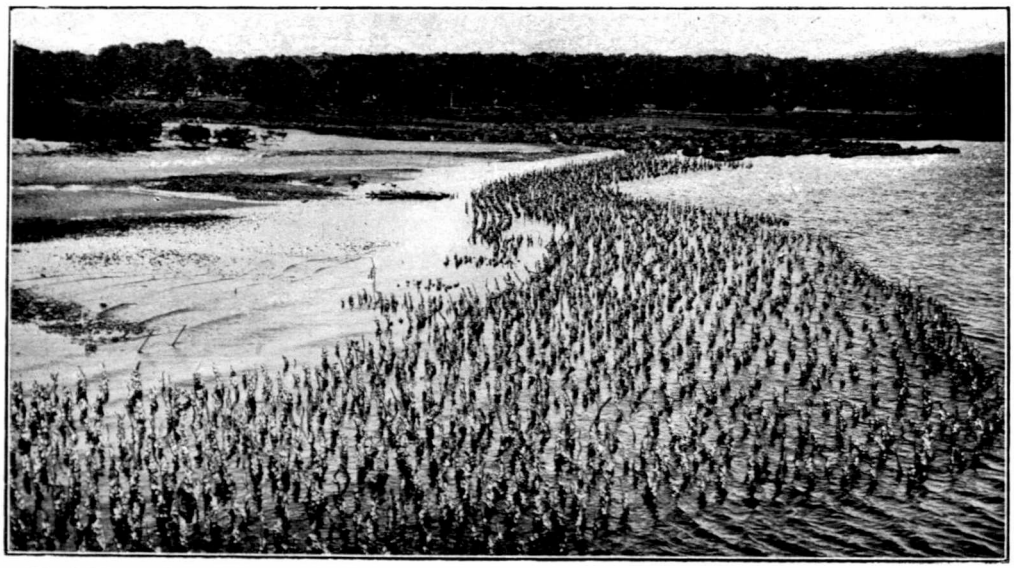
[Photo.—*T. C. Roughley.*

STONE CULTIVATION.

Stone is used either broken up into small boulders or cut into flat slabs. When the former method is adopted the broken stone is piled into heaps and arranged in rows varying from a foot to many feet in width, laid either direct on the bottom if it is firm or supported on long poles if it is soft. When the oysters are old enough to be removed they are knocked off and complete their development on a firm, level bottom or on wire-netting trays. In other cases the stones with the attached oysters may be transported to a maturing ground and laid in a single layer along poles to keep them off the mud. When stone slabs are used they are stuck into the mud in pairs, one leaning on the other, forming an inverted "V"; in this case, owing to the larger size of the stones employed, the oysters are not removed until ready for market. The reason the stones are inclined is to present an upper and under surface, for it is found that far greater numbers of spat attach to the latter than to the former. When the oysters are about a year old, the stones are reversed, each one being turned to lean on its neighbour, the surface which was formerly uppermost now being underneath. In this manner both sides are utilised to secure the maximum catch of spat.

Stones can be laid in heaps efficiently only where the water is clear, otherwise large accumulations of sediment will prevent the attachment of spat. This method is used at Port Macquarie near the entrance and on the Brunswick River, while stone slabs are used extensively on the George's and Clyde rivers. On one lease alone on the George's River there are upwards of half a million such slabs under cultivation;

Black Mangrove sticks tied together in bundles to catch spat. Many miles of such bundles line the foreshores of the Manning River. [Photo.—*T. C. Roughley.*



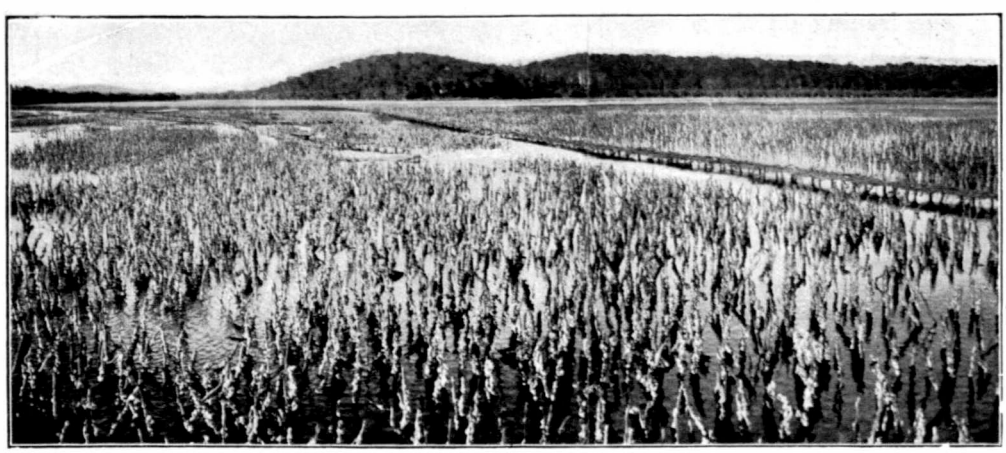
Black Mangrove sticks, originally laid in bundles, are stuck into the mud singly and upright when the oysters are about 12 months old, and here remain till the oysters are mature. Myall River, Port Stephens.

[Photo.—*T. C. Roughley.*

these measure roughly two feet long, one foot wide, and four inches thick. They were cut from a sandstone quarry on the foreshore, and towed to the lease by means of launches and punts.

STICK CULTIVATION.

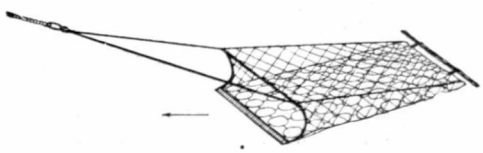
Cultivation with mangrove sticks has been carried on most extensively at Port Stephens for upwards of twelve years, and its more recent introduction into the Hawkesbury River has led to its widespread adoption there. The stone lining the foreshores at Port Stephens is not adapted to oyster culture on account of its great hardness, and the lessees were left with no other alternative but to use the mangroves which occurred there in abundance; on the Hawkesbury River, however, mangrove sticks are employed principally on the mud flats offshore, the foreshore



The most extensive Mangrove maturing ground on the coast of New South Wales. Bundabah, Port Stephens.

[Photo.—*T. C. Roughley.*

A close view of oysters, 16 months old, maturing on Mangrove sticks, Hawkesbury River.
[Photo.—*T. C. Roughley.*

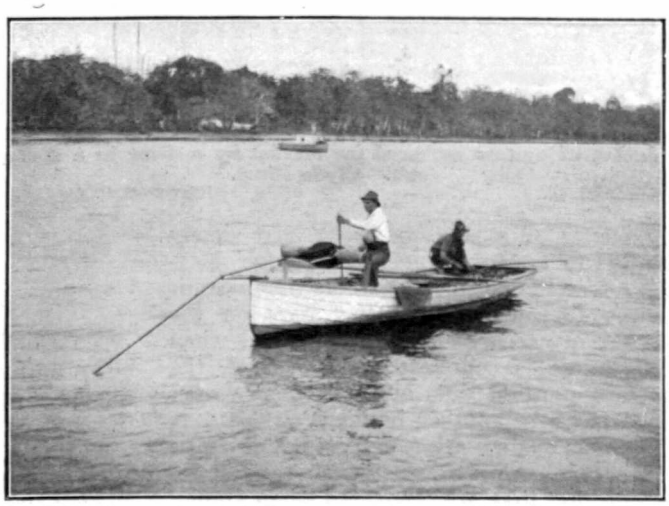


An oyster dredge. It is hauled in the direction shown by the arrow, and scrapes the oysters off the bottom as it proceeds.
[*T. C. Roughley*, del.

leases being cultivated by means of sandstone boulders which everywhere abound.

When laid to catch the spat, the sticks are bunched very close together by being (1) arranged in bundles shaped like a bell-tent; (2) laid across a rack to a depth of about a foot; or (3) stuck into the mud in a slanting position, each stick leaning on its neighbour. The reason the sticks are packed closely is because a far greater catch of spat is secured than when they are arranged singly, due probably to the eddies which are created in the crevices, for matter suspended in the water tends to collect in such eddies. The bundles are left in their original position until the shells of the young oysters are sufficiently well formed to withstand handling, usually from six to twelve months; they are then loaded on to punts and towed upstream into bays and creeks which are being fed continually by fresh water from their sources. Here the sticks are stuck into the mud singly, and upright, from one to two feet apart, and are allowed to remain there until the oysters are ready for market, when they are again lifted, taken ashore, and the mature oysters knocked off, sorted, and packed into 3-bushel bags to await shipment to Sydney. The sticks from first to last are submerged at high tide and exposed when the tide is low.

On rivers, such as the Manning and Bellinger, where the bulk of the oysters are grown on deepwater beds, sticks are used solely for the purpose of catching spat to

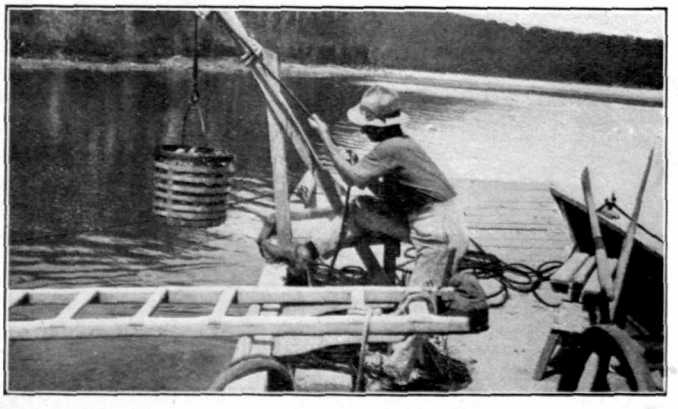


Dredging for oysters which are not uncovered by the tide. The dredge is dragged over the bottom as the man at the winch hauls the boat towards the anchor. Karuah River, Port Stephens.
[Photo.—*T. C. Roughley.*

stock the beds. Here the sticks are tied together in bundles and laid on wooden poles, at right angles to the shore and current. When the attached spat is from twelve to fifteen months old, it is knocked off into a punt and towed to the deep-water beds where it is shovelled into the water to be gathered when mature.

DREDGING FOR OYSTERS.

Oysters grown on beds which are not uncovered by the tide are usually recovered by means of an oyster dredge. This consists of an iron frame with a rectangular opening which leads into a net composed of iron rings and closed at the rear end. It is operated as follows: A boat is anchored for'ard and is then rowed back a distance of thirty or forty yards, the anchor rope being payed out over a hand winch as it proceeds. Having travelled the desired distance, the dredge is lowered and secured by means of a rope, and the boat slowly hauled to the anchorage, the dredge dragging over the bottom the whole time. As it moves forward the loose oysters on the bottom are scooped into the net, and when the course is completed it is raised, the oysters emptied out, and the boat rowed back to begin another haul.



Bucket of oysters gathered for market by a diver in a diving suit. Clyde River.

[Photo.—*T. C. Roughley.*

Dredge oysters are usually a better shape than those grown on the foreshores for the reason that they are separated when young, and, by lying loose on the bottom, have a chance to correct such irregularities of growth as may have been caused by their crowded condition when growing on the sticks. It frequently happens that good catches of spat are obtained naturally on dead shell or gravel on a deep-water bed; these are recovered along with those which had caught originally on the mangrove sticks.

DIVING FOR OYSTERS.

On the Clyde River, oysters are frequently obtained by men in diving suits. A diver descends into the water, a bucket is lowered to him, and he proceeds to gather the marketable oysters which are either growing naturally or have been dumped on the bottom to mature. Many years ago diving for oysters was an extensive industry; in most cases diving suits were used, but for a considerable time South Sea Islanders were employed on the George's River to gather the oysters without the aid of a suit.

Prior to the year 1870, when the mud-worm (*Polydora ciliata*) began to cause havoc amongst the oysters grown on the dredge beds, most of the oysters marketed in New South Wales were obtained from those sources, but as the ravages of the worm spread from river to river, dredge beds were abandoned and cultivation between tide levels concentrated upon, until at the present time only a small proportion of the oysters marketed is the product of deep-water leases, a few rivers only having remained free or comparatively free from the pest.

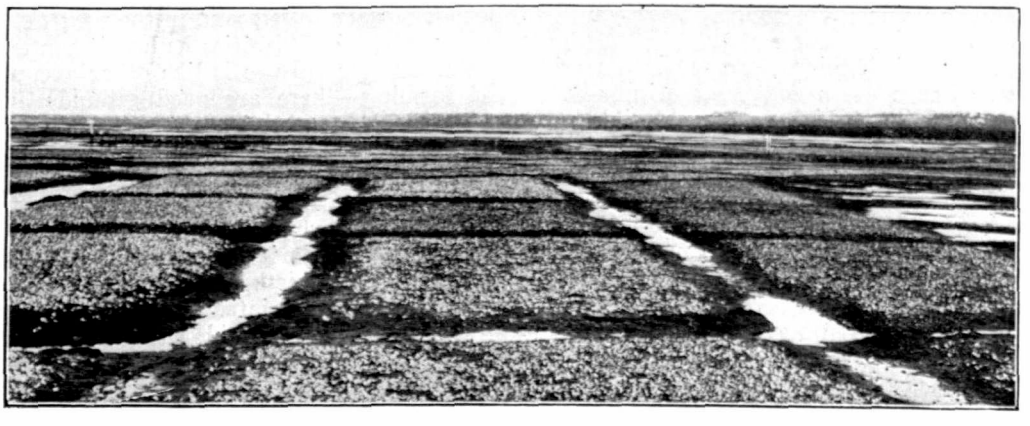
WIRE-NETTING TRAYS.

An excellent method of maturing oysters is by means of wire-netting stretched over frames of sawn timber and supported above the bottom on wooden posts. The oysters used to stock these trays are obtained from various sources—from the artificially cultivated oysters caught on Black Mangrove sticks, from stone slabs and boulders, from the naturally occurring oysters attached to the bases of the Grey or White Mangrove

Wire-netting trays used for maturing oysters gathered, when young, from stones and Mangrove sticks. Hunter River.

[Photo.—*T. C. Roughley.*

(*Avicennia officinalis*) and its pneumatophores (aerial roots), and from the rocks high up on a lease where the tide covers the oysters for a few hours only each day and where growth is consequently slow. Wire-netting trays offer several advantages over other methods of cultivation, inasmuch as (1) the oysters it is intended to mature on them must be laid down singly or at most in bunches of two or three, consequently the individual oysters have room to expand and to improve their shape; (2) the height of the tray can be regulated and the best level for ensuring the maximum amount of growth obtained; (3) a free circulation of water about the oysters is provided, and (4) they are comparatively free from pests. A disadvantage is the limited life of the galvanised wire and the wooden frames, the former lasting only from two to three years. In order to obtain the best results, all oysters grown on sticks should be finished off on wire trays, when such irregularities as are caused by an oyster growing round



Shell beds used for maturing oysters. This flat consisted originally of soft mud, but has been top-dressed with large quantities of dead shells and carefully drained. George's River.

[Photo.—*T. C. Roughley.*

a stick, leaving a groove in the exterior of the shell when detached, are largely corrected. The market value of mangrove oysters is considerably increased by this means.

There are few rivers of New South Wales on which trays are not used to some extent; they are probably most popular on the George's River, where one lessee alone has an aggregate length of upwards of two miles of them.

SHELL-MATURING BEDS.

It is very rarely found that a flat bared at low tide is sufficiently level and of a suitable consistency to mature oysters laid in direct contact with the surface. Sand is useless for the purpose; it is too unstable and gets between the shells, preventing complete closure of the valves, while soft mud will not sustain an oyster for long, and once it is completely submerged it quickly smothers. The best maturing beds are composed of deal shells, or finely broken stone or gravel, and on several rivers of New South Wales much labour has been expended in levelling ground and laying out these materials. On the Bermagui River, a solid foundation of Spotted Gum (*Eucalyptus maculata*) logs has been laid over an extensive area, and a top-dressing of dead shells has ensured a good permanent bed on which succeeding generations of oysters are laid to mature. On the Wallaga Lake, where large deposits of mud cockles (*Arca trapezia*) line the foreshores, these shells have been spread over the bottom between tide levels and durable maturing beds formed. It is on the George's River, however, that the most extensive work of this nature has been carried out. Large areas composed originally of soft mud into which one would sink halfway to the knees have been heavily top-dressed with old oyster shells dug up from below the mud, drains cut to low-tide level, and very fine rectangular shell beds constructed. The cost has been heavy, but their permanence repays for the expenditure involved.

MARKETING THE OYSTERS.

When the oysters are removed from the stone, sticks, trays, dredge, &c., the mature specimens are loaded into standard 3-bushel bags, while those that are immature are relaid on the beds or trays to complete development. The bags are shipped by boat or rail to Sydney, whence they are distributed by commission agents throughout the city, suburbs, and country districts. The price received per bag varies from £3 to £4 10s., according to quality. The length of time taken for oysters to reach a stage which may be designated average quality is usually about three years; under very favourable conditions two years may suffice, and when seasons, situations, &c., are adverse, it may take the oysters four years to mature. The shells of fast-growing oysters are softer than those of specimens grown more slowly; they do not carry so well in the bag, and their market value frequently suffers in consequence.

There were 28,380 bags of oysters produced in New South Wales during 1924. Of these, a considerable proportion was exported to the southern States, on the shores of which the commercial oyster of New South Wales (*Ostrea cucullata*) does not occur.

The shells which accumulate in the shops of Sydney and its suburbs are regularly collected, and either burnt for lime or ground into grit for bird feed.

The cultivation of oysters in New South Wales is developing steadily. Given suitable ground, an industrious, intelligent cultivator can make good money. Fortunes have been made out of the industry, and doubtless fortunes remain to be made. But it must not be thought that the oyster grower has a perfectly smooth path to tread. I hope to tell you, in the next issue, of some of the difficulties he has to contend with. Oyster culture is like other avenues of farming—there are good grounds and poor grounds, good seasons and bad ones, and there are pests which must be continually combated in order to ensure an adequate harvest, which alone makes the industry worth while.

The great majority of oyster growers are Australian by birth, and many returned soldiers were repatriated on to leases. With the assistance of scientific effort it is hoped that the pitfalls into which the pioneers of the industry stumbled, may be avoided, and the way made smoother for men who in the past have battled through unaided.

PART IV.

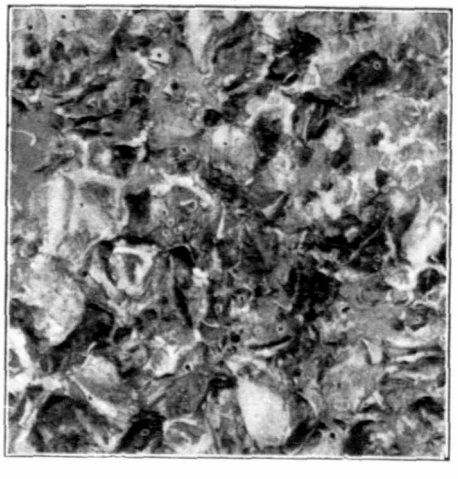
The Pests of the Oyster.

IT has been calculated that if all the eggs of oysters were to be fertilised and were to live and grow to maturity they would fill up an entire bay in a single season, while the fifth generation of descendants from a single female would make more than eight worlds as large as the earth, even if each female spawned but once.*

An oyster may, during each spawning season, eject several millions of eggs, and of these probably not more than two develop into adults. The wastage that takes place during the development from the egg to the adult oyster is therefore enormous, and it is the purpose of this article to describe some of the factors contributing to the loss.

The early free-swimming stage of an oyster's life is its most hazardous period. We have seen in a recent issue of the AUSTRALIAN MUSEUM MAGAZINE that, when an oyster spawns, the eggs from the female and the sperms from the male are cast direct into the water after the manner of most fishes. They are at once at the mercy of wind and tide, they provide food for a host of other animals, and many adverse conditions may work for their destruction. Mullet (*Mugil spp.*) are often attracted to the region of the spawning oysters, and the eggs and embryos are strained from the water and freely devoured. The number thus consumed, if allowed to develop to maturity, would probably have been sufficient to stock the whole river with a prolific crop. The survivors soon begin to swim, but their movements are very feeble, and they are carried about by currents which may take them out to sea or leave them stranded on the foreshores with each receding tide. Sudden changes of temperature and salinity kill off large numbers, and everywhere are the gaping mouths of molluscs, crustaceans, and numberless other animals waiting to absorb them. Daily their numbers diminish as the dwindling army battles on to that critical stage when the individuals must cease to roam, when they must either find some clean stable object in the water to which they may cement their shells or perish. They cannot swim powerfully enough to search for such objects, but must trust to the fortunate course of the current to carry them to their vicinity. At this period the death-rate must be very high; large numbers settle on to mud and are quickly smothered, others are carried backwards and forwards with the tide and never encounter any surface suitable for their future sedentary life.

The oyster cultivator now begins to take a hand. He cannot protect the swimming oyster from its numerous perils on account of its microscopic size, but by placing large quantities of suitable material in the water he does give many an opportunity to live in situations where they must have perished without his aid. Having once secured the fixed oyster, the cultivator can often assist it to evade its enemies or save it from destruction after it has been attacked.



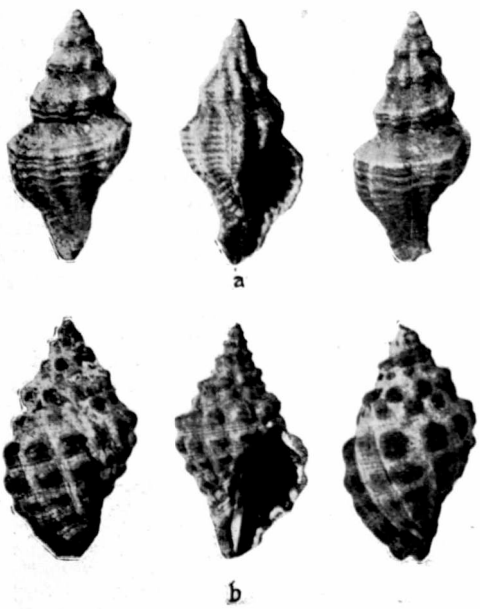
Oysters 2 months old destroyed by the Common Borer. Practically every oyster shows the small characteristic hole drilled by the borer's radula. Natural size.

Photo.—*T. C. Roughley.*

*Brooks, "The Oyster," p. 50.

BORERS OR DRILLS.

Probably the worst pest young oysters have to contend with is the boring whelk, a shellfish provided with a tongue-like rasp, or radula, by means of which a hole is bored through the oyster's shell, the flesh then being extracted piecemeal through the opening. This radula is a wonderful adaptation of nature which allows quick and easy penetration of a shell, hard enough, one would imagine, to offer an effective resistance to the attacks of so small an animal. The mechanical drilling action is assisted by the secretion of sulphuric acid, which converts the carbonate of lime of the

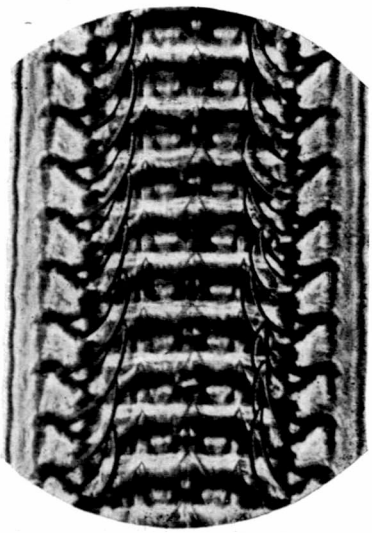


(a) The Common Borer (Xymene hanleyi). (b) The Black Borer (Drupa marginalba). These borers possess rasp-like tongues, by means of which holes are drilled in the shells of oysters, and the flesh is then extracted piecemeal through the openings. Natural size.

Photo.—*T. C. Roughley.*

oyster's shell into sulphate of lime, and thereby greatly reduces its resistance. The hole made is clean-cut and circular in outline.

Oyster borers are most common where the salinity of the water is fairly high; they cannot withstand water of low salinity, and are therefore found in greatest numbers near the entrances of rivers or in those streams into which little fresh water flows.



The radula of the Common Borer (Xymene hanleyi). By means of the minute horny teeth on this strap-like rasp, holes are bored through the shells of young oysters. Magnified 240 times.

[Photomicrograph—*T. C. Roughley.*

Fortunately, in such waters the crops of young oysters are usually very much greater than in those of lower salinity, for there is less sediment in suspension, and the stones, sticks, and other material which offer surfaces for attachment remain very much cleaner. It frequently happens that far greater numbers of oysters attach themselves than can ever grow to maturity owing to their overcrowded condition. The borers, however, quickly thin them out.

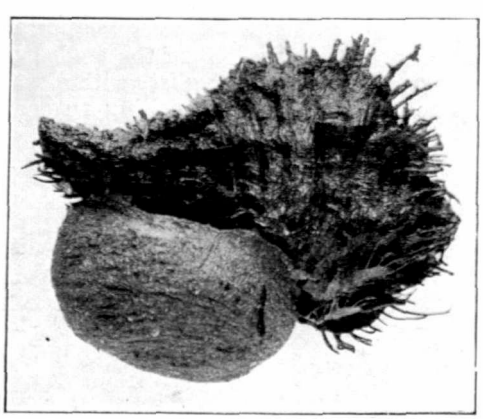
Egg-cases of the Common Borer (Xymene hanleyi). The eggs and developing larvae are protected by a semi-transparent membrane attached to shells and other objects in the water. Magnified 6 times.

Photo.—*T. C. Roughley.*

Larvae of the Common Borer (Xymene hanleyi). Upwards of a hundred larvae may be enclosed in each egg-case. Magnified 9 times.

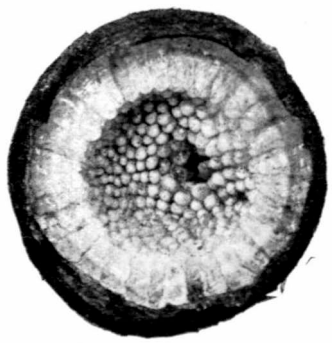
[Photo.—*T. C. Roughley.*

An oyster cultivator can do little more than gather those borers he finds and destroy them by throwing them ashore well beyond high tide level or by dipping them into boiling water; the destruction of the eggs whenever found must also eventually result in a considerable reduction of their numbers. Heavy rain with resulting freshets either kills off the borers or drives them out to sea.



The Hairy Borer (Cymatium parthenopeum) with egg-case attached. This borer makes a comparatively large hole, and is capable of penetrating the shells of adult oysters. Two-thirds natural size.

[Photo.—*T. C. Roughley.*



The interior of the egg-case of the Hairy Borer. The eggs are contained in the conical semi-transparent capsules. Natural size.

[Photo.—*T. C. Roughley.*

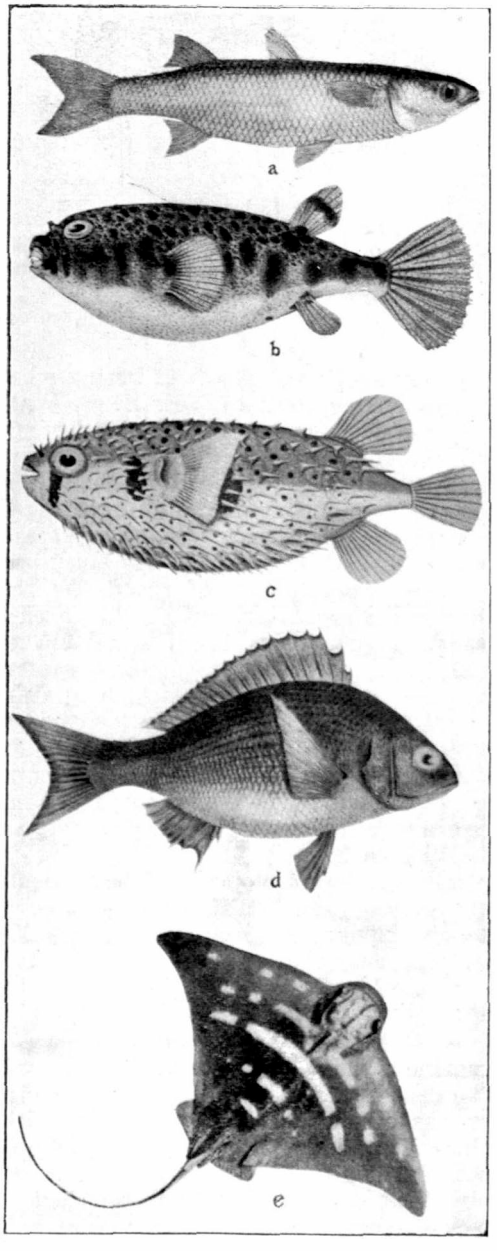
There are three species of boring whelks found on the coast of New South Wales: (1) the common borer (*Xymene hanleyi*), which grows to a length of about an inch, and deposits its eggs in dome-shaped capsules about one-eighth of an inch in diameter; these it attaches to the surfaces of oyster shells or stones; (2) the black borer (*Drupa marginalba*), of about the same size as the preceding, but characterised by blunt protuberances, black in colour; and (3) the hairy borer (*Cymatium parthenopeum*), a larger species which attains a length of four inches and deposits its eggs in a parchment-like case held firmly against the under surface of the shell. The common borer, as its name implies, is by far the most prevalent, and few, if any, rivers are entirely free from it.

The greatest destruction I have seen on the coast of New South Wales has occurred on the Bruswick River and at Port Macquarie near the entrance. The natural habitat of boring whelks is in the sea, where the salinity of the water is always high; here they take toll of great numbers of marine shellfish. One has only to examine the dead shells of such molluscs washed up on the ocean beaches to see the result of their depredations; a large proportion is usually found with the characteristic small circular holes drilled through the shells.

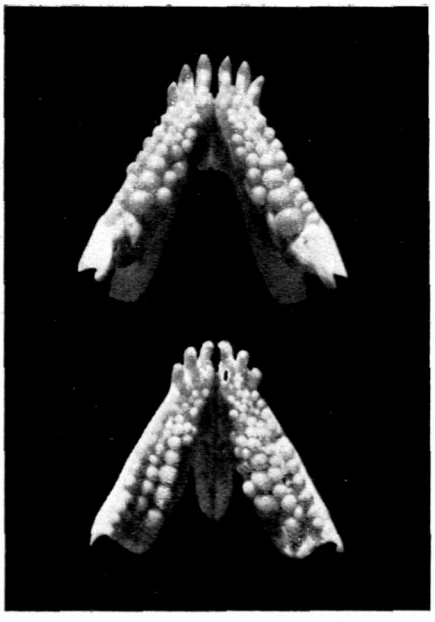
FISH PESTS.

In addition to the mullet, which, owing to the feeble development of its teeth, is capable of devouring the oyster only when

it is a soft-bodied creature of microscopic size, there are other types of fish whose teeth are well adapted to crushing the hard



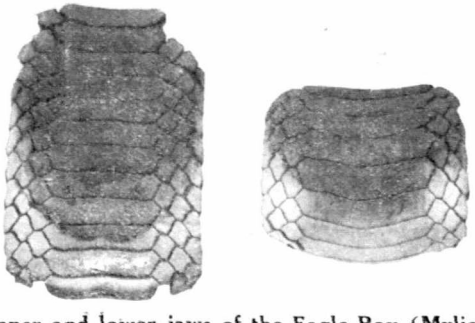
Fish Pests of the Oyster. (a) Mullet (Mugil sp.). (b) Toadfish (Spheroides hamiltoni). (c) Porcupine Fish (Dicotylichthys punctulatus). (d) Bream (Sparus australis). (e) Eagle Ray (Myliobatis australis).



Upper and lower jaws of the Bream (Sparus australis). The canine teeth are used for wrenching oysters free and the molars for crushing the shells. Natural size.

[Photo.—*T. C. Roughley.*

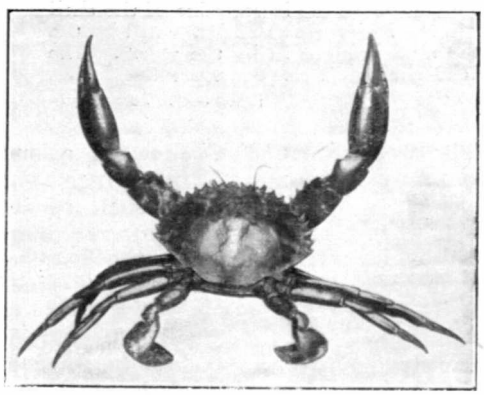
shells of attached oysters. Of these, the greatest pests are (1) the common toad fish or toado (*Spheroides hamiltoni*), which has the teeth modified into a kind of beak resembling that of a parrot; (2) the porcupine fish (*Dicotylichthys punctulatus*), with jaws similar to that of the toado; (3) the bream (*Sparus australis*), with a set of canine teeth used for wrenching an oyster



Upper and lower jaws of the Eagle Ray (Myliobatis australis). The upper half of each plate is seen to be considerably worn through crushing oysters and other shellfish. One-half natural size.

[Photo.—*T. C. Roughley.*

from its attachment and molars adapted to crushing the shells; and (4) the eagle ray (*Myliobatis australis*), whose powerful jaws are provided with hard, pavement-like plates. The eagle ray may attain a width of four feet, and is capable of crushing the shells of fully-grown oysters. The damage done by these fishes is considerable, and the only means of protection afforded to the oyster cultivator is to fence off the leases with stakes or wire netting. The labour and expense involved are of course not warranted unless the destruction caused by the fishes is extensive.

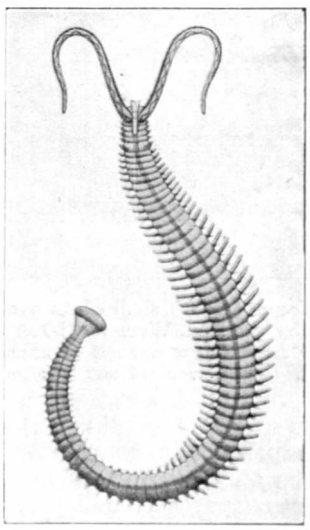


The Mangrove Crab (Scylla serrata). Oyster shells are crushed between the powerful nippers and the meat devoured. One-ninth natural size.

[Photo.—*T. C. Roughley.*

CRABS.

The oyster grower frequently suffers much loss from the onslaughts of the mangrove crab (*Scylla serrata*), a large species, deep greenish brown in colour, which may attain a width of two feet overall. The oysters are crushed between the powerful nippers, most of the damage being done at night. While the young oysters suffer most at the hands of this crab, fully-grown specimens are by no means immune, particularly if their growth has been rapid and their shells not very thick and hard. The visits of the crabs are periodical, and, if concentrated in considerable numbers, a whole bed of oysters may be destroyed in a few days. The mangrove crab is more common on the North than on the South Coast, the Macleay River probably suffering to a greater extent than any other. The only remedy so far devised is to improvise fences to keep them off the leases.



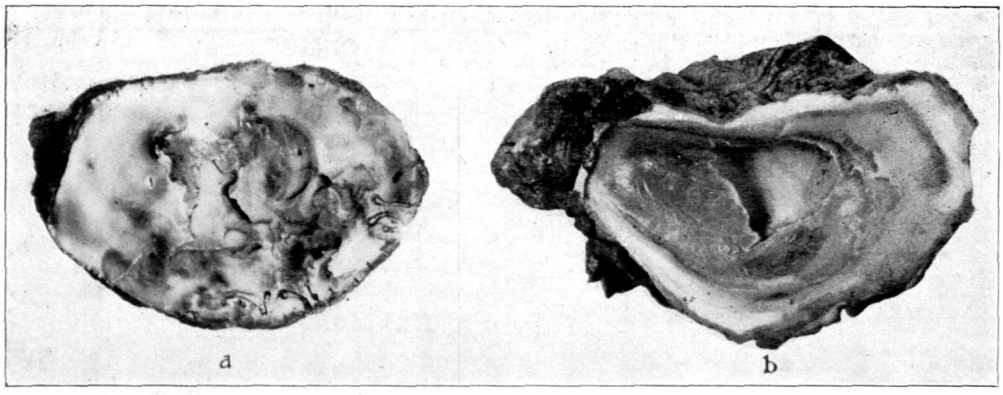
The Mud Worm (Polydora ciliata). This is the greatest pest of the oyster in Australian waters. It lives inside the shell, where it accumulates a quantity of mud, eventually killing the oyster. Magnified 5 times.

[*T. C. Roughley*, del.

MUD WORM.

The greatest enemy the oyster has on the coast of New South Wales is the mud worm (*Polydora ciliata*). So great an influence has been exercised by this worm that it has altered the whole type of cultivation practised. The first extensive damage caused by it occurred in the Hunter River about the year 1870, but whether it was introduced there in oysters imported from New Zealand at that time, or whether it already occurred on the coast and some favourable conditions enabled it to increase enormously, cannot at present be determined. Certain it is that in recent years it has played very great havoc with the oysters. Mr. Thos. Whitelegge, a well-known zoologist and then on the staff of the Australian Museum, investigated an outbreak at this locality in 1890.* From the Hunter it has

* For the results of Mr. Whitelegge's investigations, see "Records of the Australian Museum." —Vol. I, 1890, p. 41.



(a) Upper (right) shell of an oyster, showing the channels on the lower edge of the shell made by the Mud Worm. (b) A large "blister" in the lower (left) shell formed by the oyster secreting a deposit of shelly matter over the mud brought in by the worm. The mud has been washed out to show the extent of the cavity. Three-fourths natural size.

[Photo.—*T. C. Roughley.*

spread to practically every river on the coast. The only oyster-bearing waters to remain entirely free from it are Bonville Creek and the Bellinger and Nambucca rivers, while in the Manning the damage done is very slight.

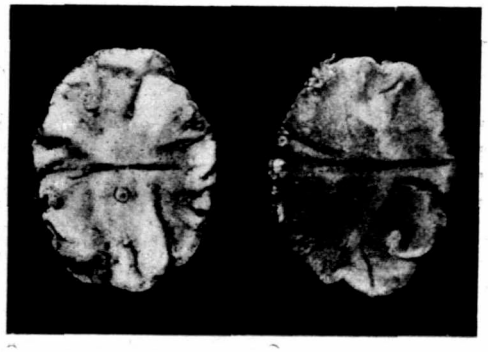
Prior to the outbreak on the Hunter, the market requirements were satisfied almost wholly by oysters grown on areas never bared by the tide, often at considerable depths, the term "dredge oysters" being generally applied to them because of the fact that a dredge had to be used to gather them. These beds were the first to suffer, and in a short time it was found to be practically impossible to raise an oyster to maturity in such situations. At the present time dredging is confined to a few rivers only on the coast, principally the Manning and the Bellinger. As the dredge beds were abandoned, cultivation along the foreshores was concentrated upon, and at the present time the bulk of the oysters marketed is the product of foreshore leases. The quality and size of the oysters has deteriorated somewhat in consequence, for those matured on dredge beds grow more quickly, attain a greater size, and retain their condition for longer periods of the year. But for the mud worm it is questionable whether any cultivation at all would be carried on along the foreshores, for the natural beds below low-tide level are probably more than sufficient to supply the requirements of the whole of Australia.

The worm is reddish-yellow in colour, and rarely grows more than an inch long. It either swims inside the shell of the oyster when it is feeding and the valves are open or is carried in with the in-going stream of water. Entrance is gained usually when the worm is in the young or larval stage and is very small. Once inside it constructs two tubes close together at right angles to the edge of the shell, and begins to collect mud from the exterior of the shell and from other objects in the vicinity. This mud accumulates on the inner surface and sets up irritation of the tissues in contact with it. The oyster proceeds to deposit a layer of shell over the mass, completely enclosing it in a separate chamber. Further attacks by worms gradually upset the normal economy of the oyster, its living space becomes restricted, it begins to weaken, and a stage is eventually reached when it is no longer capable of secreting shelly material over the mud and at last succumbs.

The worm thrives best in muddy situations, but is by no means confined to them. It is most prevalent near or below low-tide level. Oyster growers combat it by keeping material to which the oysters are attached well off the bottom by means of poles, wire netting supported on posts, &c., and if any beds are found to be badly infested the oysters are raised for a week or two to near high-tide level, where they are exposed to the heat of the sun for long

periods and are covered by the tide for very brief intervals; by this means the worms are killed and the oysters suffer little or no injury.

In order to allay any fear on the part of the oyster consumer, it should be pointed out that oysters whose shells are infected with worms are not by any means detrimental when eaten. The worms, except in rare cases, are completely isolated from the oyster's body, and there is little or no risk of any being partaken with the meat. It is not a parasite on the oyster, but simply builds its mud home inside the shell for the protection afforded.



Upper and under surfaces of the Wafer (Leptoplana australis). This worm is suspected of killing large numbers of oysters.

[Photo.—*T. C. Roughley.*

WAFER.

The turbellarian worm known as the wafer (*Leptoplana australis*) is thought to cause much damage to oyster life, but in what manner it kills the oyster has not been definitely determined. It is commonly found feeding on the meats of recently dead oysters, and is of course blamed for their death, but it is difficult to see how entrance can be gained inside a live oyster. However, its frequent association with dead oysters places it under grave suspicion, and it is therefore destroyed whenever found.

OCTOPUS.

The octopus (*Polypus cyaneus*) does not prey on the oysters directly, but uses them to build its cone-shaped nest. Crawling over beds on which loose oysters lie, it attaches its suckers to several of them and carries them to its appointed home. Piling them in a circle round it, the octopus soon gathers a heap of oysters up to two feet high and hides in the hollow in the middle. Because of the weight of the oysters above them and the accumulation of sediment, many of the lower ones are smothered. It is not an uncommon sight to see numbers of such nests on a flat below low tide, and where the octopus is prevalent a careful watch must be kept for their nests and the animals speared. The octopus has a decided preference for water of high salinity, and quickly makes for sea at the approach of a freshet.

FRESHETS.

Freshets, caused by flood waters pouring down from the source and tributaries of a river, must be accounted amongst the major enemies of oyster life. Very great damage is periodically caused by them, particularly on several rivers on the North Coast of New South Wales. Extensive areas of oyster-bearing grounds may be covered with water of very low salinity, in some cases with water fresh enough to drink, for such long periods that the bulk of the oysters succumb. Even greater damage may be caused by the sediment brought down by the fresh water, which may accumulate on the beds to a depth of several inches, resulting in the death of every oyster beneath it. On the Richmond, Clarence, and Macleay rivers practically all the oysters, with the exception of those grown in the estuaries, have at intervals been exterminated by these causes. A certain amount of fresh water is decidedly beneficial to oysters; those growing in the salt water of the estuaries in normal seasons rarely thrive so rapidly as do those situated in the more brackish water upstream. It is the water of very low salinity and the sediment which are fatal to them.

TIMBER BORERS.

Timber borers such as *Limnoria*, *Sphaeroma*, and the dreaded "cobra" (*Teredo*) not only limit the class of wood available for oyster culture, but shorten the life of all timber used, and thus are classed by cultivators amongst the oyster pests. If it were not for the destruction caused by these animals, the available supply of sticks and logs suitable for oyster cultivation would be limitless, whereas now only three or four species of trees are sufficiently resistant to

withstand their attacks long enough to enable the oysters to mature. Where logs are to be employed for supporting stones with attached oysters, the most durable timbers are the prickly tea-tree (*Melaleuca stypheliioides*) and the turpentine (*Syncarpia laurifolia*). It is necessary that the bark of both species be left intact. In situations where the logs sink partially or wholly into the mud most timbers are but little affected by marine borers, for the coating of mud gives a certain amount of immunity from attack. The bark of these trees is unsuitable for the attachment of oysters; for this purpose the black mangrove (*Aegiceras majus*) is the ideal timber; it is strongly resistant to borers in even very small dimensions, and the sticks of this tree have been used to a far greater extent in cultivation than those of any other species. The frames (mostly sawn hardwood), to which wire netting is attached as a support for maturing oysters, do not last as a rule more than three years, the length of time depending on the type of timber employed and the prevalence of borers in the river, some waters being more seriously infested than others.

CONCLUSION.

There are a number of other pests which either continually do minor injury to the oysters or may periodically cause a heavy mortality in isolated rivers. Amongst these may be mentioned the red weed (*Falkenbergia*), which at intervals invades Port Macquarie in such quantities that it lies thick on the beds, where it rots and liberates gases which kill large numbers of oysters; the balloon weed (*Colpomenia*), which grows on loose oysters and, becoming distended with gas, floats away with them; the boring sponge (*Cliona*), which honeycombs the shells of the older oysters; and mussels (*Mytilus*), which may grow on the beds in such dense clusters that the oysters remain poor and in some cases die. Space will not allow of a detailed description of these pests; sufficient has been written to show that the oyster's life is full of peril, and that the cultivator has a busy and somewhat uncertain time waging warfare on its numerous enemies, in order that the initial crop may be given an opportunity to grow and fatten to provide a festival for the most cunning and relentless of all the oyster's enemies—man himself.

Sydney: Alfred James Kent, Government Printer—1929.