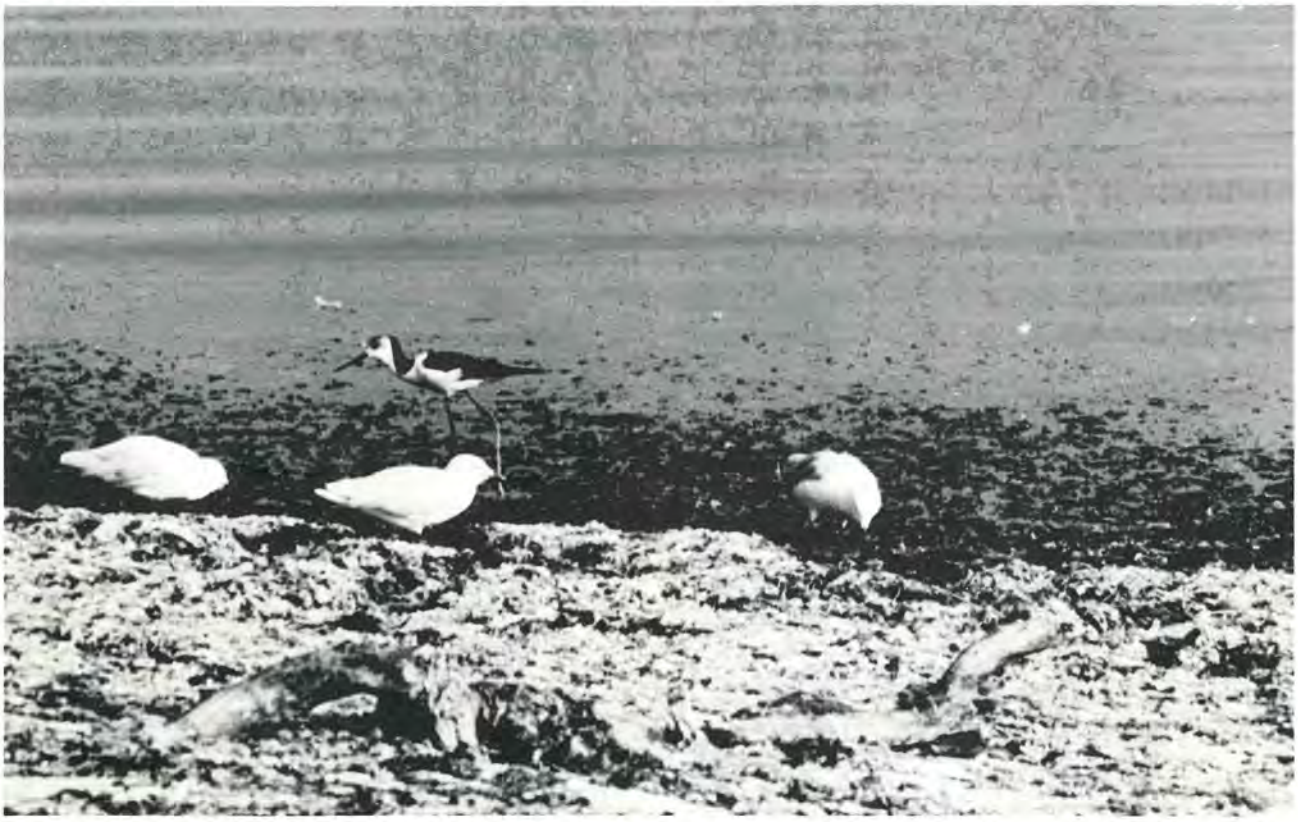
D... Conservation & Environment

PEEL – HARVEY ESTUARY PROGRESS

NO 1
SEPTEMBER 1983

BULLETIN NO 146

THE STATE OF THE ESTUARY



Stilt and Silver Gulls Feeding Among Decomposing Algae

The history of the algal problem

The algal problem in the Peel-Harvey estuary apparently dates from the mid-1960's and air survey photographs of January, 1967 show weed accumulations off the Coodanup shore. The first recorded complaints of decomposing algae date from 1969, although fishermen had complained about an algal slime fouling their nets as early as 1960. The problem increased in the early 1970's.

Masses of green algae accumulated in the shallows on the shores of Peel Inlet, fouling the beaches and decomposing to a black ooze smelling of hydrogen sulphide. The major problem alga at this time was *Cladophora* (goat weed) which grew on the bottom in cotton-wool like balls. It floated to the surface and drifted to the shores where it decomposed.

In 1974 the Peel Inlet Management Authority began the "cosmetic" operation of removing mounds of rotting algae from the beaches using tractors equipped with rakes.

Phase 1 of the Peel-Harvey Estuarine System Study, which began in 1976, aimed to find the causes of the excessive growth of algae in Peel Inlet. Research showed that the main cause was the increase in plant nutrients, nitrogen and phosphorus, discharged into the estuary from agricultural drainage. The increase in phosphorus was particularly great and the principal recommendation for management was that the amount of phosphorus available to algae should be reduced by one means or another. Phase 2 of the study, which began in 1982, aims to determine how best this reduction can be achieved.

The state of the estuary in 1983

Conditions in the estuary have changed greatly during the last decade. *Cladophora* has been replaced by other green algae in Peel Inlet and since 1978 the blue-green alga *Nodularia* has turned the waters green, especially in Harvey Estuary. This produces an even more unpleasant odour when washed onto the shores. Some of these changes are attributable to variation in rainfall and river flow and the consequent amount of phosphorus delivered to the estuary. However there have also been long-term changes in the estuary, some of which show that the condition of the estuary has deteriorated. Nevertheless the fishery still flourishes and in 1983 catches of king prawns were the greatest on record. Crab catches too were greater than in recent years although juvenile crabs entered the estuary later than in good years.

Above: Diatoms and Nodularia Filaments

The algae

Cladophora was the main nuisance alga through the 1970's, but recently it has been largely replaced by other green algae: first by *Chaetomorpha* (rope weed) and *Enteromorpha* and in 1983 by *Ulva* (sea lettuce). These, like *Cladophora*, are washed onto the shallows by wind and waves where they rapidly decompose to a black ooze.

These algae seem to have given little trouble in Harvey Estuary, but it now suffers annual blooms of the blue-green alga *Nodularia* in spring-summer (except in 1979 a year of low river flow). These blooms appear to be getting progressively worse. *Nodularia* grows as chains of microscopic cells that float in the water, but on calm days it floats as a scum on the surface. This drifts to the shore and decomposes with a nauseating, sulphurous smell. It also invades Peel Inlet, but never grows as well there as in Harvey Estuary. The reason for this appears, in part at least, to be due to a poorer supply of nitrogen in Harvey Estuary compared to Peel Inlet. *Nodularia*, unlike green algae, is able to use atmospheric nitrogen.

The weed harvester and tractors operated by the Peel Inlet Management Authority, have been successful in reducing the amount of large green algae that reaches shores adjacent to housing. However, it is clearly of no use in controlling *Nodularia* with its microscopic filaments, even when these form a film at the surface as they do in calm weather.

Since 1982, another blue-green alga, *Oscillatoria*, has appeared, principally in Harvey Estuary. It forms a black slime over the bottom and, when it is growing actively, this slime breaks off and floats to the surface.

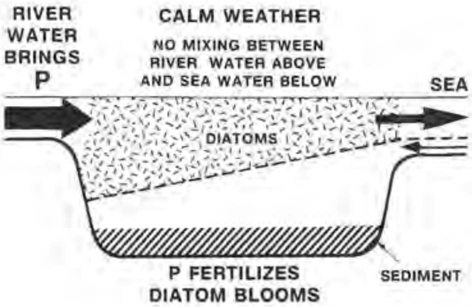
During the *Nodularia* blooms, most fish leave Harvey Estuary, but there have been fish kills there and in parts of Peel Inlet where *Nodularia* accumulates. These deaths have probably been caused by a lack of oxygen in the water. Great numbers of worms and other small animals on which fish feed have also died. However, despite the algal blooms and interruption of fishing in Harvey Estuary during the *Nodularia* blooms there is no evidence of reduced fish production.

Right: Nodularia Filaments

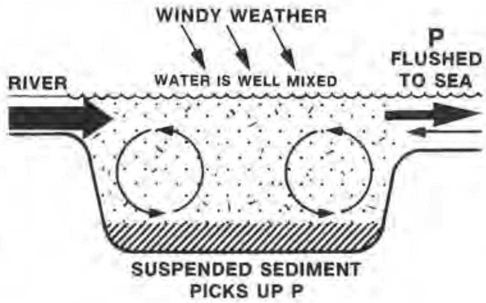
The phosphorus cycle

Winter — Spring (June — Sept.)

Each winter a load of nitrogen and phosphorus is delivered to the estuary in nutrient-rich river water. Some of this goes straight out to sea and some of the nitrogen is lost to the atmosphere. However, much of the phosphorus stays in the estuary and is used by plants or is added to the sediment store. What happens is that the phosphorus is either used by diatoms and other microscopic single-celled green algae or is picked up by suspended sediment particles, which then drop to the bottom.

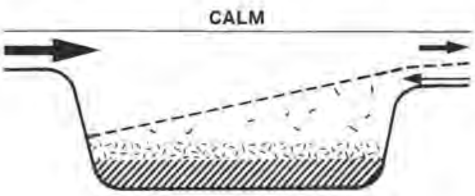


DIATOMS FLOURISH

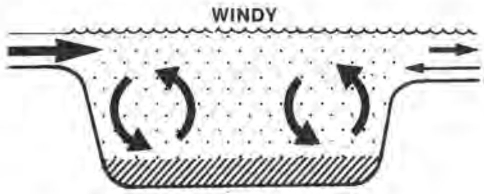


Spring

The diatoms grow rapidly in the water from July to September and when they die they settle to the bottom and are decomposed by bacteria. The bacteria use up the oxygen in the bottom water and this causes phosphorus to be released into the water, both from the decaying diatoms and from the bottom sediment.



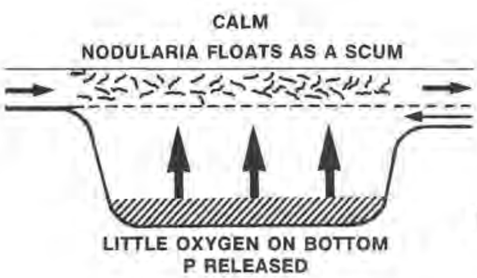
DIATOMS DIE AND DECOMPOSE



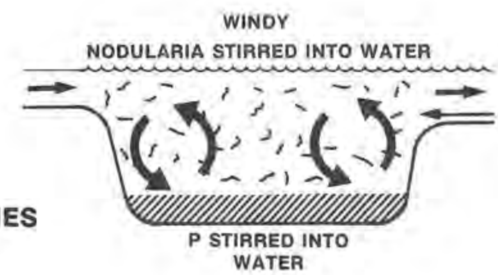
BACTERIA USE UP OXYGEN AND P IS RELEASED FROM DECOMPOSING DIATOMS AND THE SEDIMENT

Spring — Summmer (Sept. — Dec.)

In the warm water of spring, this new phosphorus stimulates growth of the *Nodularia* spores which have lain dormant in the sediment. *Nodularia* multiplies rapidly and from October to January the blooms can be so dense that diatoms and other plants cannot get enough light for their growth. At this time its growth is only limited by the amount of phosphorus available to it. *Nodularia* is also favoured in Harvey Estuary because it can fix its own supply of nitrogen direct from the atmosphere, just like legumes such as subclover.



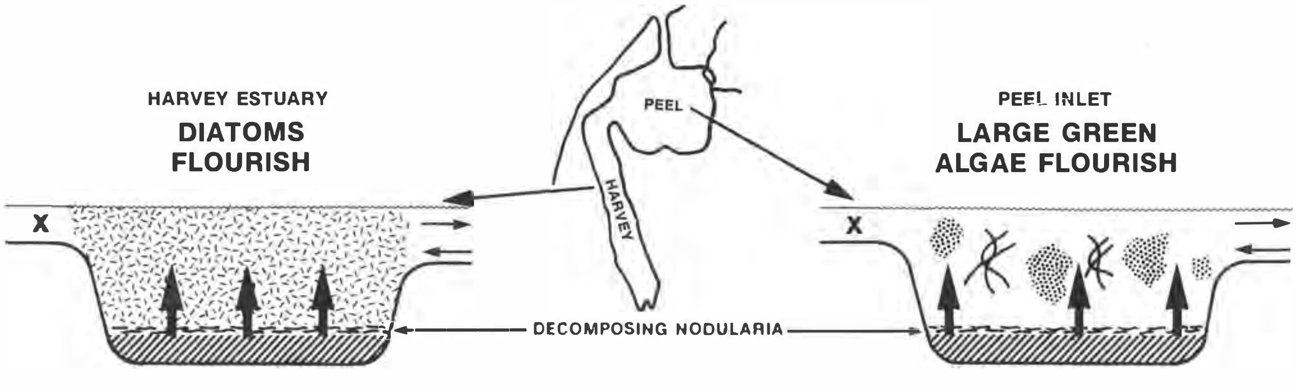
NODULARIA FLOURISHES



Summer — Autumn (Jan. — May)

Eventually, in December or January, the *Nodularia* blooms die out. This is probably because the water is now too salty and the supply of readily available phosphorus runs low. This was well illustrated in January 1982 when heavy rains delivered fresh water and a new load of phosphorus into the estuary and revitalized the *Nodularia*. This resulted in the biggest bloom ever.

When *Nodularia* decomposes in late summer, a fresh load of phosphorus is released into the water. This fertilises another crop of nuisance algae which flourish in the warm, salty water of summer and autumn.



P RELEASED FROM DECOMPOSING NODULARIA AND SEDIMENT

The role of the sediment

The estuarine sediment thus plays an important role in supplying phosphorus to the various kinds of algae. It picks up phosphorus from the water, stores it, and releases it again for algae to use. When the water is well oxygenated, the sediment only releases phosphorus slowly, but when there is little oxygen in the water, and it is alkaline, the sediment releases phosphorus rapidly.

More phosphorus comes into the estuary each year in drainage water than is flushed to the sea by river flow or is lost by tidal exchange. Just as a large store of phosphorus has built up in soils of the coastal plain, so too in the estuary a large store has accumulated in the sediment — the estuary's soil. Not all of this phosphorus is readily available to plants, any more than insoluble rock phosphate is to crops. However, the amount of phosphorus available to algae from the sediment store is increasing every year.

This is one reason why the estuary is deteriorating, even though the amount of superphosphate used in the catchment has levelled off in recent years. In consequence we are now concerned lest before long there will be such a large store of phosphorus in the sediment that it will supplement the external supply sufficiently to feed the algal blooms, even after there has been a considerable reduction in input. We hope that, with the co-operation of farmers, the supply of phosphorus from the land will be greatly reduced before this stage is reached and that the available sediment phosphorus will then be exhausted quickly.

A limited amount of fertiliser may have been a good thing for the estuary in the past. Algae flourished and fish catches doubled in the 1970's as compared with the 1950's and 60's. But too much is undoubtedly a bad thing and that's where we are now in 1983. Decaying algae use up oxygen, and fish and the small animals on which most of them feed cannot live without oxygen. There have been fish deaths in recent years and there will be more in the future, until the amount of phosphorus available to algae can be reduced.

Instructions to readers:

- further pamphlets will be issued from time to time. Each will be distinguished by a characteristic number eg. Bulletin 146 No. 1 or Bulletin 146 No.7.
- when requesting a pamphlet from the Department please specify the Bulletin and pamphlet numbers.
- Pamphlets are available free of charge to organisations and individuals concerned with the estuary.
- For further information contact the Department of Conservation and Environment, 1 Mount Street, Perth, or phone 322 2477.

References

Department of Conservation and Environment, Report No. 9. The Peel-Harvey Estuarine System Study. 1980.

Bulletin No. 88. The Peel-Harvey Estuarine System Study: a report by the Estuarine and Marine Advisory Committee to the Environmental Protection Authority. 1981.

Bulletin No. 117. Eutrophication of the Peel Inlet and Harvey Estuary. 1982 (Poster)

Bulletin No. 118. The Peel-Harvey Estuary. 1982 (Poster)

Department of Conservation and Environment

PEEL – HARVEY ESTUARY PROGRESS

BULLETIN No 146

NO 2
OCTOBER 1983

CURRENT MANAGEMENT OF THE ALGAL BLOOMS

The algae in Peel Inlet

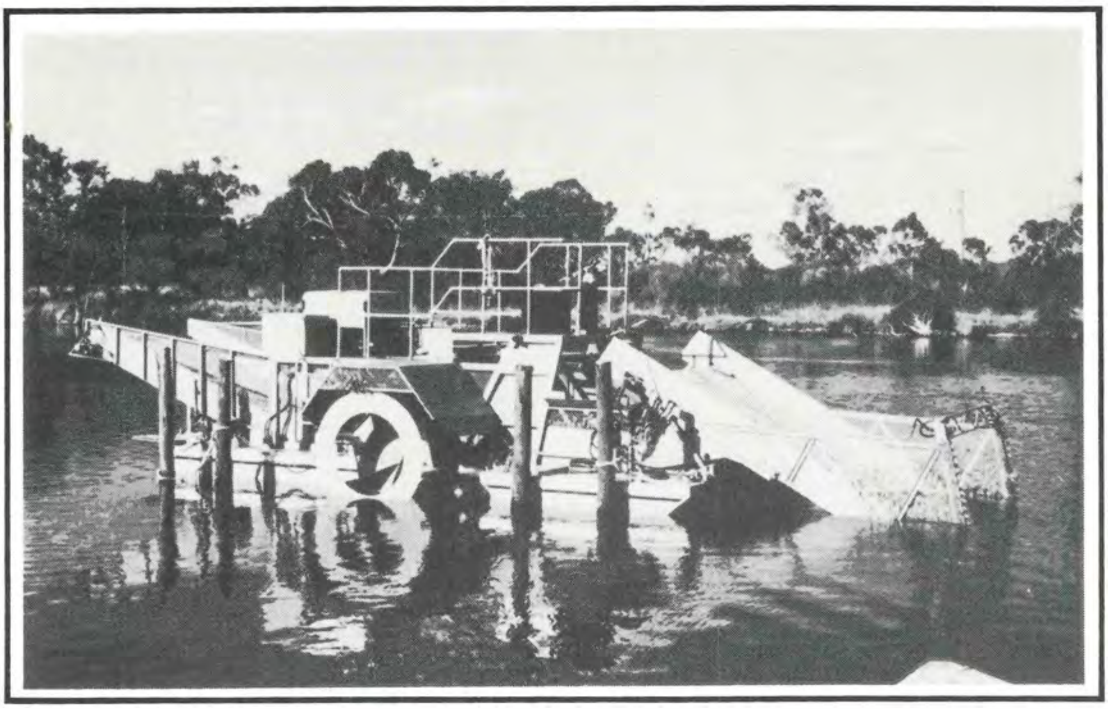
Large green algae of several kinds grow abundantly throughout Peel Inlet and at times they are carried towards the beaches by winds and currents. They accumulate in the shallows where they begin to decay, often in huge mounds, and are driven onshore by wind and waves. The rotting algae give off hydrogen sulphide and other noxious gases.

The first recorded complaints about algae accumulating on beaches around Peel Inlet date from 1969.

Removing weed from the beach

Since 1974, tractors equipped with rakes have removed mounds of rotting algae from beaches near residential areas at Novara and Coodanup. The algae are raked into piles to dry, and trucked away.

This has achieved the short-term goal of cleaning up the public beaches but it does nothing to prevent weed growth, and is not without side effects. The tractors damage foreshore vegetation, and collect a high proportion of sand with the algae, depleting the beaches. Moreover, the cost is considerable — about $70,000 a year.



Offshore weed harvesting

Early in 1983 the Peel Inlet Management Authority acquired a new $260,000 weed harvester from the United States. This collects algae from where they grow in about ½ to 1½ metres of water. The aim is to harvest the weed before winds and currents carry it to shore and it begins to rot. It is scooped up onto a conveyor and transferred to a transport unit which carries it to the shore. Here it is loaded into trucks for removal. Between February and September 1983 a total of 531 tonnes (wet weight) of *Ulva* (sea lettuce) and 52 tonnes (wet weight) of *Chaetomorpha* (rope weed) was removed from the estuary by harvesting.

The harvester has been successful in greatly reducing the amount of algae reaching the shores, but the tractors are still needed to cope with occasional mass beachings when storms bring weed ashore from large areas of the estuary. The area in which the harvester can work is limited by water depth and the need to transport the algae back to the shore loading facilities.

The harvested algae

Peel Inlet has been dominated by a series of different large green algae, and nobody really understands why this succession has occurred. Initially, *Cladophora* (goat weed) was the greatest problem. Subsequently it was largely replaced by *Chaetomorpha* and in 1983 by *Ulva*, all of which the harvester can easily collect. This is fortunate because when *Ulva* especially is blown onto the beaches it decomposes rapidly to a sloppy foul-smelling black ooze.

Algae — a stock feed ingredient

In the past most of the harvested algae was dumped, or used to stabilize sand dunes, and local people have carted it away to use as mulch on their gardens. Recent research has shown that it could have commercial value as a stock feed ingredient. Large scale battery hen feeding trials have had encouraging results. The algae are nutritious, and also help to bind pellets together. In addition, overseas research has shown that algae contain yolk-pigmenting agents (carotene). Chickens fed on pellets containing algae lay eggs with yelloer yolks, so it can replace imported carotene.

The amount of algae harvested would need to be increased to a minimum of about 100 tonnes of wet weed per week to make the operation economic. The Waterways Commission is investigating ways to increase the harvest.

At present about 90% of the weight of algae harvested is water, but much more could be collected by using rollers to squeeze water out of the algae as they are collected on the harvester's elevating conveyor. More algae could then be taken ashore in each load, and drying time would also be saved when algae are used in making stock feed.

There is no doubt that algae can be a valuable stock feed ingredient and its commercial use is still being evaluated.

Harvey Estuary

The large algae have never given much trouble in Harvey Estuary, but since 1978 it has suffered annual blooms of the microscopic blue-green alga, *Nodularia*, in spring and early summer.

These follow the winter diatom blooms that are triggered off by the river flows, with their load of phosphorus.

Nodularia grows as chains of microscopic cells that float in the water and turn it green. On windy days it is mixed into the water, but on calm days it floats as a scum on the surface. This drifts to shore and decomposes with a nauseating sulphurous smell. It also invades Peel Inlet but fortunately never grows as well there as in Harvey.

Since 1982 another blue-green alga, *Oscillatoria*, has appeared, mainly in Harvey Estuary. It forms a black slime over the bottom and, when it is growing actively, this slime breaks off and floats to the surface.

The harvester is not designed to collect the microscopic cells of these blue-green algae, even when they form a scum on the surface of the water. This means that although it is effective in helping to keep Peel Inlet's beaches clean, different solutions must be found for Harvey Estuary's problems.

Long term management

Harvesting algae achieves the short-term goal of removing the nuisance from Peel Inlet's public beaches, but this only treats the symptoms not the cause of the problem — the plant nutrients that feed the algae.

Probably less than 2% of the annual load of about 120 to 160 tonnes of phosphorus entering the estuary is removed in the form of harvested algae. Long term control of the algal problem will require this load to be greatly reduced by more radical management measures, such as modifying agricultural fertilizer practices in the catchment, or diverting the nutrient rich drainage away from the estuary.

Reducing phosphorus input

A major recommendation of the Peel-Harvey Estuarine System study team's 1980 report was that every effort be made to reduce the quantity of phosphorus discharged into the estuary from agricultural land.

More than 60% of the phosphorus entering the estuary comes in via the Harvey River and Mayfield Drain, at the south end of Harvey Estuary. In 1981, farmers in the Harvey River–Mayfields Drain catchments lost the equivalent of nearly 16,000 bags of superphosphate into Harvey Estuary. The 150 to 200 farmers collectively spent over $120,000 to fertilize Harvey Estuary at about one bag per acre, producing a monster crop of blue-green algae.

Since 1982 a programme has been underway aimed at reducing the amount of phosphorus lost to the estuary from farms on the deep grey sands and duplex (sand over clay) soils of the Harvey River catchment.

Altering fertilizer practices

To do this it is necessary to modify the present techniques of superphosphate application.

Two things are needed:

- to apply phosphorus only at a level necessary to maintain production.
- to supply it in a less soluble form to minimise leaching from sandy soils.

The amount of fertilizer required to maintain production can be determined by soil testing. This tells farmers how much phosphorus is available in the soil bank, their 'super bank', and how much needs to be added. Surveys by the Department of Agriculture on about 150 farms in the area show that, despite heavy leaching, soil reserves have gradually built up over the years. Of the paddocks on deep sands, nearly half have built up reserves to the point where phosphorus can be left off, at least for one year, without affecting production. However, sulphur, another nutrient in super, must still be applied annually and potassium is also likely to be needed. For the duplex soils, over 90% of paddocks surveyed required no added phosphorus for at least one year; in most cases probably for several years. The aim is to build up reserves, and then apply only enough phosphorus to maintain the reserves and maintain production. This means less phosphorus pollution of the estuary, and savings for the farmers.

"Coastal Super"

A new slow release ("Coastal") superphosphate developed by C.S.B.P. and the Department of Agriculture is helping farmers to reduce application rates because much of the phosphorus will remain in the soil instead of being leached out in winter rains.

Application rates could be halved to an average of about 100kg/ha of "Coastal" superphosphate — and still maintain production on sandy soils where sufficient reserves have built up. Significant reductions are also possible on heavy soils, again without any loss of production. This represents a substantial potential saving for farmers.

Already about three quarters of farmers on deep sands in the Harvey River catchment and about one quarter of the farmers on duplex soils are using the new fertilizer.

Will the new slow-release fertilizers solve the estuary problem?

There is no doubt that, if application rates are reduced and the slow release fertilizers used, then less phosphorus will be washed into the estuary. If the rates of phosphorus applied can be halved without reducing yields — which now looks possible — phosphorus losses to drains could be reduced by the same amount. This should greatly alleviate the algae problem.

Phosphorus runoff into the estuary is being monitored to gauge the effects of the changing fertilizer practices. Much of the phosphorus washed into the drains each winter comes from superphosphate applied that year. This is because ordinary superphosphate is highly soluble and hence easily dissolved and washed into drains. However, some of the phosphorus in the soil from previous applications is also leached to drainage. The amount depends on the soil type and the size of the phosphorus reserve. Where this reserve does not contribute much, then the use of slow release fertilizer at reduced rates will have a quick effect. Where there is a large reserve of phosphorus in sandy soils, beyond the reach of grass roots (only about 10cm), the loss of phosphorus to drainage will continue for longer.

Other methods of reducing the loss of phosphorus to drainage are also being studied, such as the use of deep rooted plants and improving the capacity of sandy soils to retain phosphorus (and water) by adding bauxite residue to the soil.

Reducing phosphorus losses to the estuary will be a significant help, but this alone may not solve the algal problem. Control of the algae may well require a combination of this and other management measures.

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Bulletin No. 117. Eutrophication of the Peel Inlet and Harvey Estuary. 1982 (Poster).

Bulletin No. 118. The Peel-Harvey Estuary. 1982 (Poster).

Bulletin No. 133. Peel-Harvey Catchment Update for Farmers 1983. (series of newsletters, co-produced with Department of Agriculture, Harvey, Western Australia).

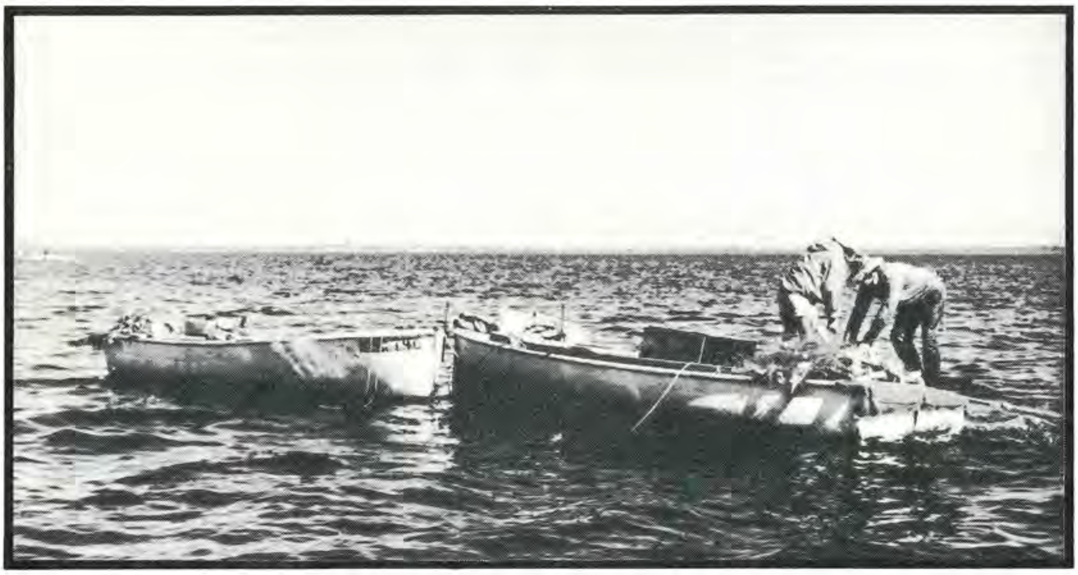
Department of
Conservation &
Environment

PEEL – HARVEY ESTUARY PROGRESS

BULLETIN No 146

NO 3
NOVEMBER
1983

THE ALGAE AND THE FISHERY



Estuaries are very productive environments, and provide ideal conditions for rapid growth of fish. There are also fewer large fish-eating fish than in the sea along the coast, so there is less predation by fish on the juvenile fish.

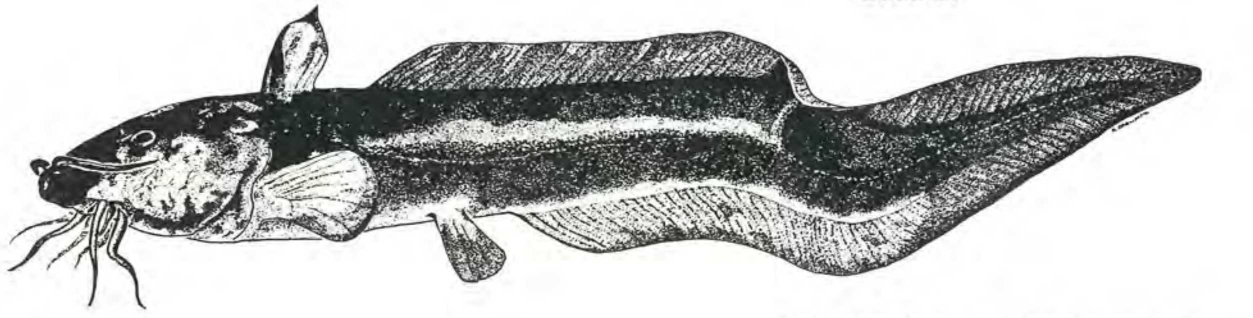
The Peel-Harvey estuary supports the largest professional fishery in Western Australia and fishermen take 600 to 900 tonnes of fish from the estuary each year, worth over $1m. It also has one of the largest amateur fisheries, and many locals and holidaymakers enjoy fishing, crabbing and prawning.

The Fish

The fish fauna of the estuary was sampled during 1979-81, using beach seines, gill nets, and otter trawls. This was part of a joint research programme by Murdoch University and the Department of Fisheries and Wildlife. Over fifty species of fish were identified. The main commercial species are cobbler, yellow-eye mullet, sea mullet and whiting. Blue manna crabs, river prawns and King prawns are also important.

Amateur anglers catch mostly cobbler, tailor, mulloway, whiting and yellow-eye mullet throughout the estuary. In addition, herring, skipjack and garfish are caught off the bridge at Mandurah. Nets principally yield sea mullet, yellow-eye mullet, cobbler and tailor. Crabbing is popular, and hundreds of people can sometimes be seen netting King prawns in the inlet channel.

Cobbler



Fish drawings by Ken Browning

How fish use the estuary

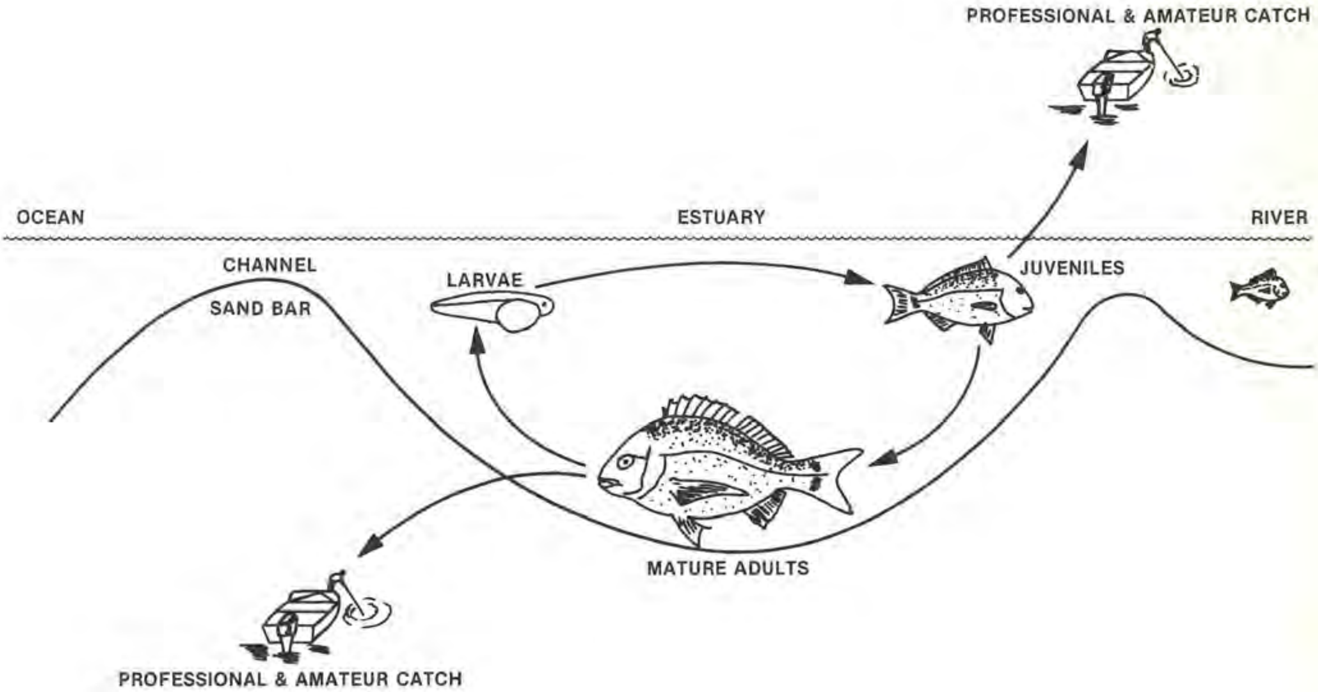
The fish use the estuary in different ways:

1. as a place where they can pass their whole life cycle,
2. mainly as a "nursery" habitat for juveniles,
3. as a place where adult fish come to feed.

There are only a few species of fish which use the estuary as a permanent habitat. They include cobbler, black bream, Perth herring, gobbleguts, yellow-tailed trumpeter and several species of hardyhead.

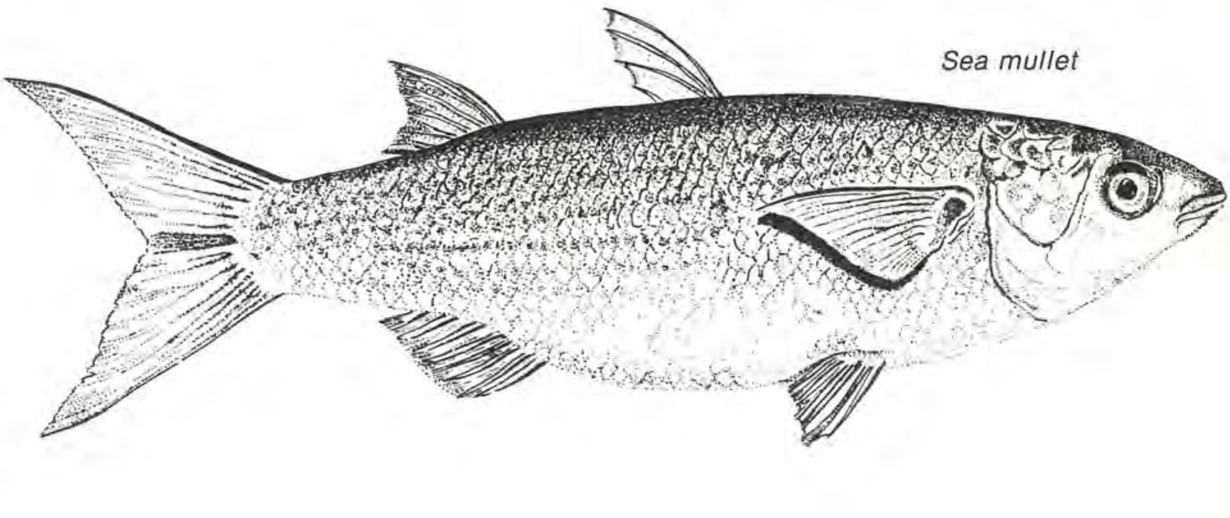
Cobbler also occur in protected embayments on the coast, but the population in the estuary is separate. They are widely distributed in the estuary, living on the bottom and feeding on snails and worms.

Black bream are now caught mainly in the rivers, principally by amateurs. They are omnivorous feeders.

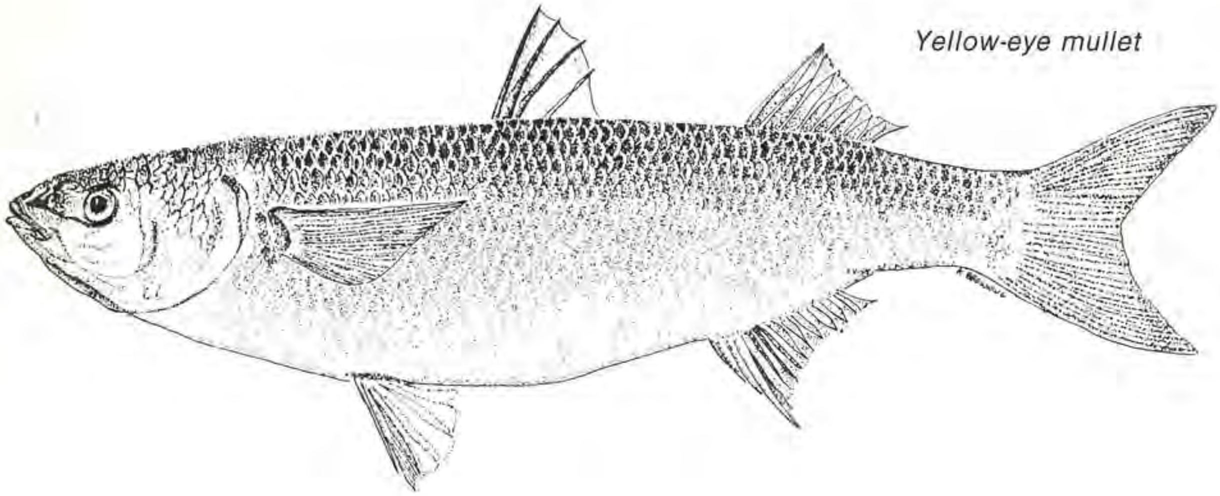


Most of the fish, including 9 of the 15 most abundant species, enter the estuary from the sea for variable periods to feed or to use it as a "nursery" where the young fish feed and grow. It is an important nursery for several marine fish, for example sea mullet, yellow-eye mullet, King George whiting, western sand whiting, tailor and mulloway.

Sea mullet are a typical example. They spawn in the ocean, and the young enter the estuary in winter and spring as very small fish. They feed in the rivers and basins on *detritus* (organic matter and bacteria on the bottom) and some small animals. They grow rapidly, sometimes reaching the minimum legal fishing size in their first year. The adult fish move back out to sea to breed.



Sea mullet



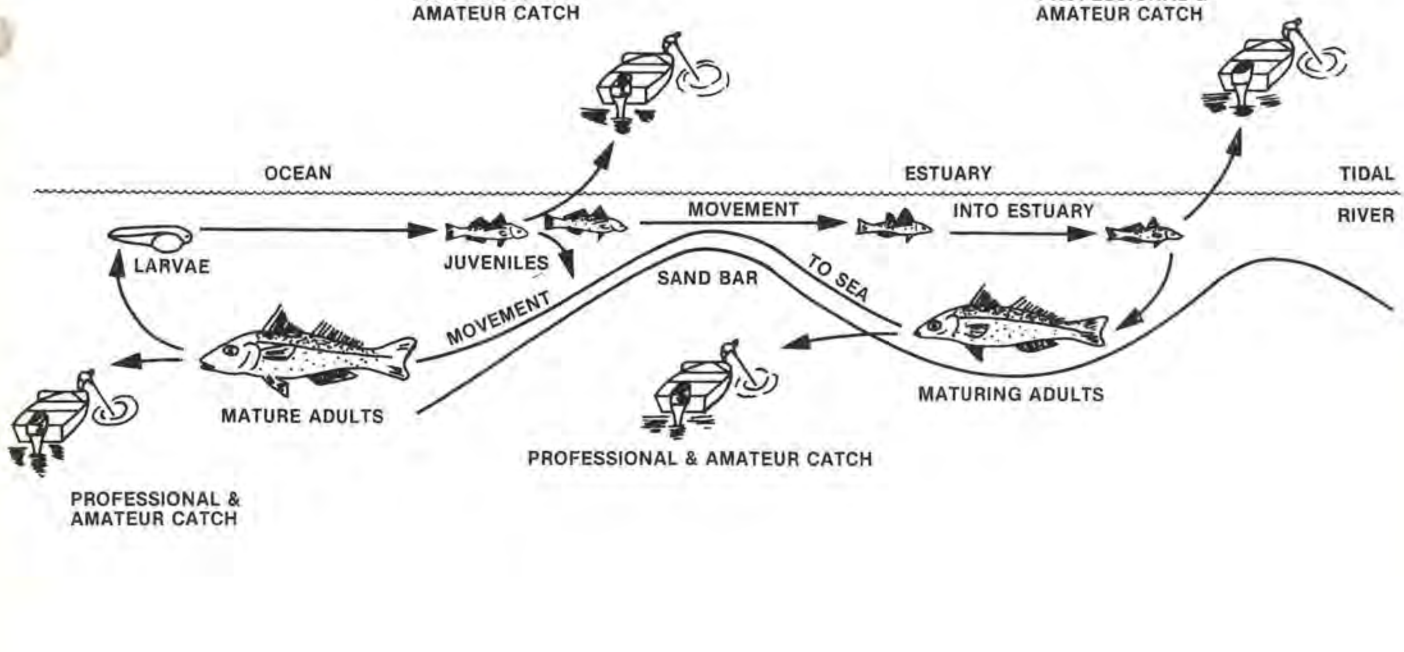
Yellow-eye mullet

Yellow-eye mullet also use the estuary as a feeding and nursery habitat. The younger ones are usually found in the rivers, and the larger ones in the basins of the estuary. Their diet is varied, including plants, snails, small shrimps and worms. They grow quickly and reach minimum legal size within two years.

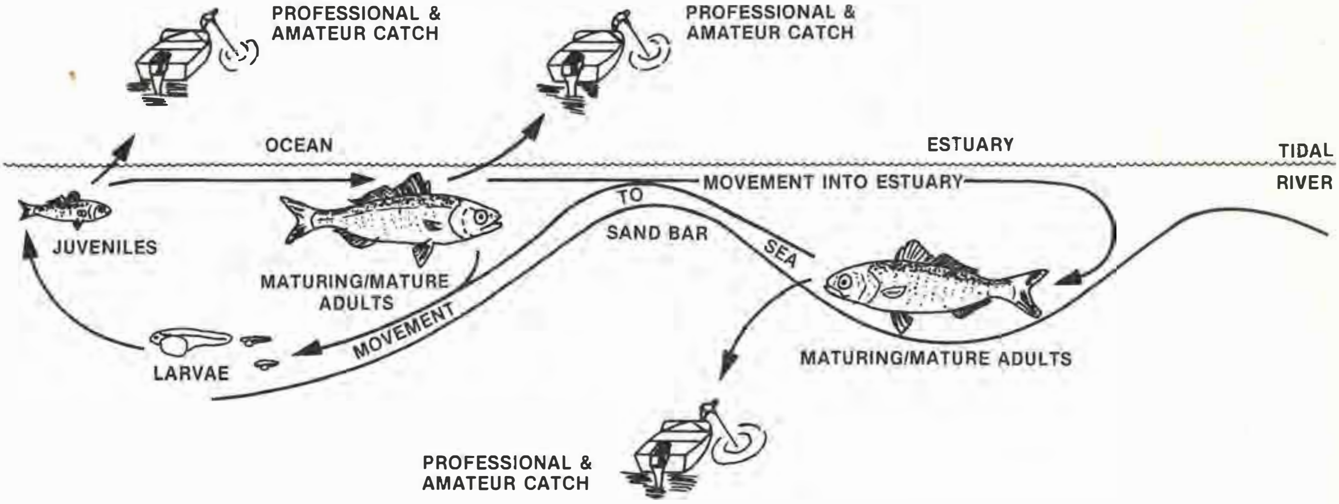
Tailor use the estuary as a nursery but spend less time there. They prefer to come into the estuary in the warmer summer months, when the water is saltier. They feed on smaller fish throughout the estuary, then move out again in winter when fresh water comes down the rivers.

Mulloway do not enter the estuary until they are several months old. They live throughout the estuary, staying mainly in the deeper basins during the day, and feeding on shrimps and fish.

King George and **Western sand whiting** occur throughout the estuary and up into the rivers but **school whiting** only come into the entrance channel. Whiting are carnivores and feed on worms, shrimps, snails and other small animals.



Some fish, like **skipjack** *(trevally)* and **Australian herring** feed and grow to maturity in the ocean. Only the adults enter the estuary to feed. They too are carnivores.



How crabs and prawns use the estuary

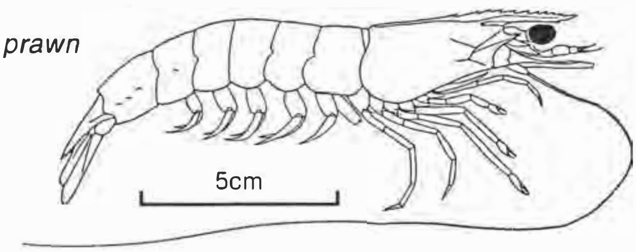
Female **blue-manna crabs** spawn in the ocean in the spring and summer months. After a short period of larval development the juveniles enter and spread throughout the estuary. They return to near the estuary mouth during winter and spring when salinity is low. In summer, when the estuary becomes saltier, they again spread throughout the estuary and into the lower reaches of the rivers. The young crabs feed and grow in the estuary, and start to reach minimum legal size for catching in summer, at the end of their first year. The crabbing season usually lasts from January to May. The young crabs leave the estuary the following winter when they are 15 to 20 months old.

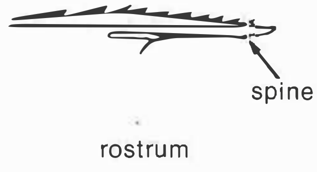
Western King prawns also spawn in the ocean, and the young go through several larval stages, drifting in the water currents and feeding on diatoms and tiny animals. The young prawns enter the estuary over the summer (November to January), and settle to the bottom. They grow in the "nursery" shallows over the summer, feeding on detritus and small animals. They migrate out of the estuary as mature prawns in the autumn (February to April) and are caught in large numbers as they go through the inlet channel.

River prawns, unlike King prawns, spend their whole life cycle in estuaries. In the Peel-Harvey system the fishery is mainly in the Murray River which they enter as mature prawns when the river flow decreases and saline water enters from Peel Inlet. They spawn all through summer and into autumn and the juveniles probably spend the winter and spring in Peel, though just where is not known.

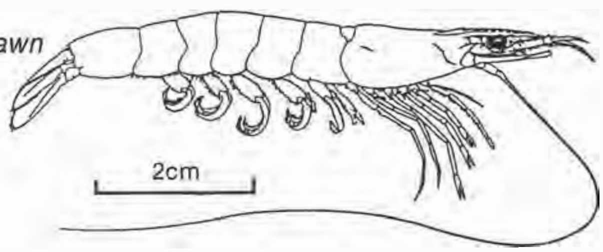
The two prawn species are much alike and are easily confused, unless carefully examined. King prawns have a single spine on the underside of the rostrum and the animals are rough to the touch. River prawns do not have a spine on the underside of the rostrum and they are smooth. The present popular fishery is based mainly on King prawns which are caught from February to May. The river prawn season is earlier, from October to January.

King prawn





River prawn



The effects of the algae

What effects are the estuary's algal problems having on the fishery?

There is evidence of a historical change in composition of the catch between 1952 and the present day. Catches of crabs, yellow-eye mullet and sea mullet have increased and in consequence the commercial catch almost doubled in the 1970's as compared with the 1960's, without a comparable increase in fishing effort. Catches of King prawns have increased dramatically in the last few years.

Commercial catches of black bream in Peel Inlet have decreased but it is not clear what causes this. The deeper water of the Murray River appears to be a more favourable habitat for this fish.

Numbers of fish and crabs have probably increased because the large green algae which now dominate Peel Inlet provide them with cover-protection from the large populations of fish-eating birds like pelicans and cormorants. The algal beds also provide a good habitat for many of the shrimps and other small animals on which the fish feed.

Decomposing masses of algae sometimes inconvenience fishermen by clogging their nets, but up until 1980 the eutrophication of the estuary was of overall benefit to the fishery.

The Effects of Nodularia

The dense blooms of the blue-green alga, *Nodularia*, which have appeared since 1980, are another matter. *Nodularia* blooms appear in spring and early summer, especially in Harvey Estuary. Commercial fishermen have reported greatly reduced catches in areas affected by *Nodularia*.

Some fish, like yellow-eye mullet, move away to other parts of the estuary. Others, including bottom-living species, such as cobbler and crabs, do not always escape the effects of the *Nodularia*. Dead fish and crabs have been found in regions where the bloom was very dense. They were probably killed by lack of oxygen in the water.

Nodularia also prevents fishermen from hauling their nets, and they are forced to either abandon the area or use the less productive gill-netting technique. Commercial fishing almost ceased to operate in Harvey Estuary during the early summers of 1980-81 and 1981-82.

Unfortunately the fish and crab catches are most affected over the peak tourist season. After the *Nodularia* bloom dies in December or January, catches recover.

The Research Programme

Joint research by Murdoch University and the Department of Fisheries and Wildlife is improving our understanding of how the large green algae and *Nodularia* affect the fish and crabs. Commercial fishermen are co-operating closely with the Department of Fisheries and Wildlife in the research. In 1982, fishermen completed daily logs of where they fished and what fish they caught. This information was analysed together with details of where and when the *Nodularia* bloom occurred, and gave a picture of how it was affecting the fishery.

In the summer of 1983, two boats will be chartered to fish in areas affected by the *Nodularia*, areas which are normally avoided by the fishermen. Their catches will help to find out how the *Nodularia* affects the fish.

The fishery and management of the algal problem

An understanding of how the large green algae and *Nodularia* affect the fishery is vital, so that management measures to reduce the algal problem can take into account the effects on the fishery, which is so important to the region. It is a question of striking a balance — most people want the estuary cleaned up, but if the job is done too effectively the fishery could suffer.

Common names and species names of the major species caught by amateur and professional fishermen in the Peel-Harvey Estuary.

Common Name	Species Name
Yellow-eye mullet	*Aldrichetta forsteri*
Sea mullet	*Mugil cephalus*
Cobbler	*Cnidoglanis macrocephalus*
King George whiting	*Sillaginodes punctatus*
Western sand whiting	*Sillago schomburgkii*
Tailor	*Pomatomus saltatrix*
Mulloway	*Argyrosomus hololepidotus*
Black bream	*Acanthopagrus butcheri*
Western river garfish	*Hyporhamphus regularis regularis*
Sea garfish	*Hyporhamphus melanochir*
Skipjack (trevally)	*Pseudocaranx wrighti*
Blue manna crab	*Portunus pelagicus*
River prawn	*Metapenaeus dalli*
Western King prawn	*Penaeus latisulcatus*

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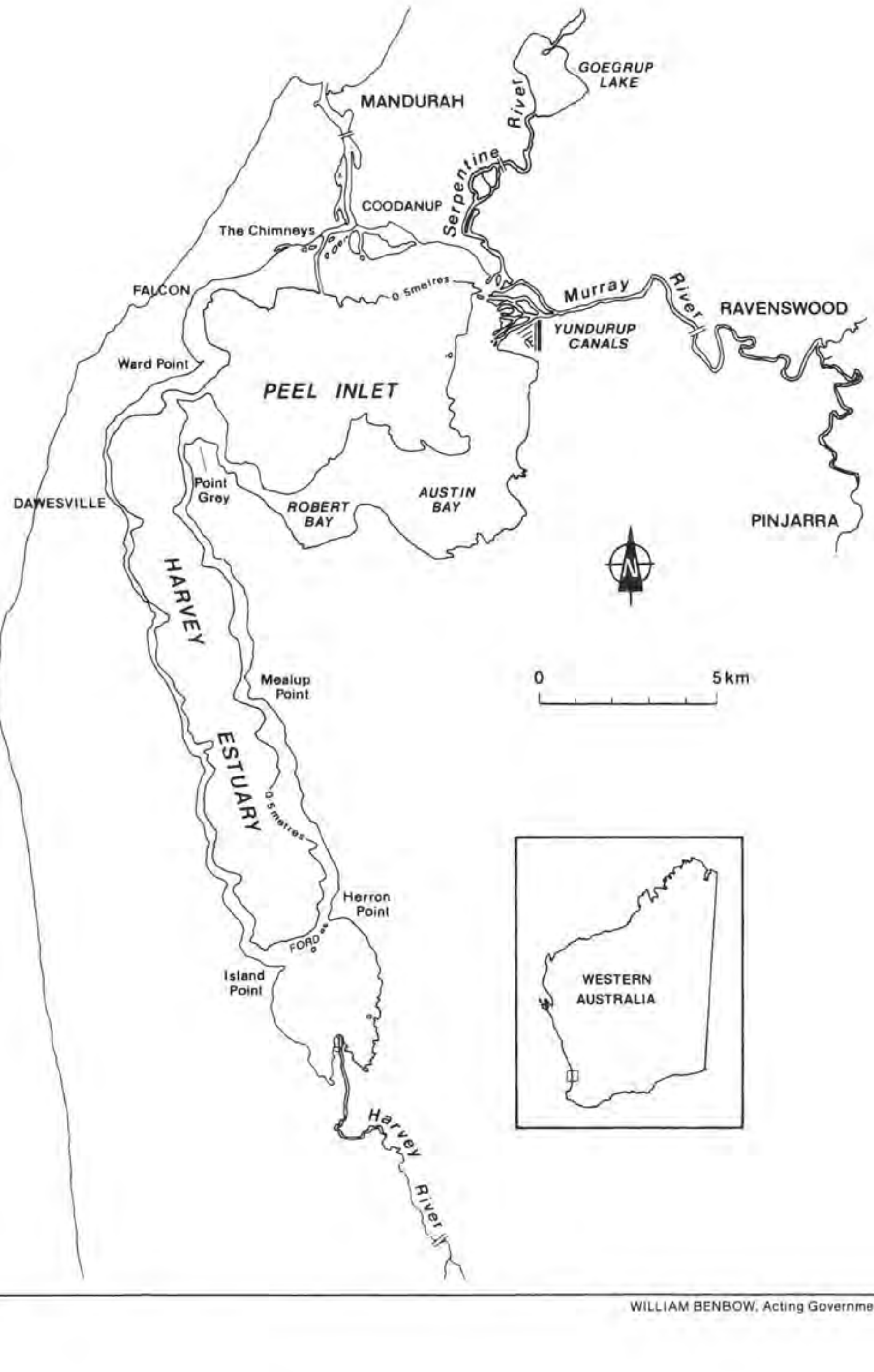

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WILLIAM BENBOW, Acting Government Printer, Western Australia

Department of
Conservation &
Environment

NO 4
JANUARY
1984

PEEL – HARVEY ESTUARY PROGRESS

BULLETIN No 146

THE NATURE AND MOVEMENTS OF THE WATER

Where the water comes from

Fresh water flows into the estuary from the Murray, Serpentine and Harvey Rivers, from agricultural drains, and a small amount comes from groundwater. In a year of average rainfall, flow from the rivers and drains is about five times the volume of the estuary. Direct rainfall onto the estuary adds another 20% to 30% to fresh water input. The annual loss by evaporation is greater than the volume of the estuary.

Sea water enters the estuary from the Indian Ocean to mix with the estuary water and estuary water is lost to the ocean. However tidal exchange is restricted by the long, narrow Mandurah channel and the small ocean tidal range.

Inside the estuary the daily tidal range is less than 10cm. However, 'tides' with a period of about a week (5 to 15 days) and up to 50cm range move a considerable volume of water between estuary and ocean. Water level is high when the barometer is low and low when the barometer is high. Because of the restricted exchange with the ocean and the extreme seasonality of our rainfall the nature of the estuary water changes greatly during the year. In a wet winter it can be fresh throughout, while in summer it is more salt than the sea.

The catchment

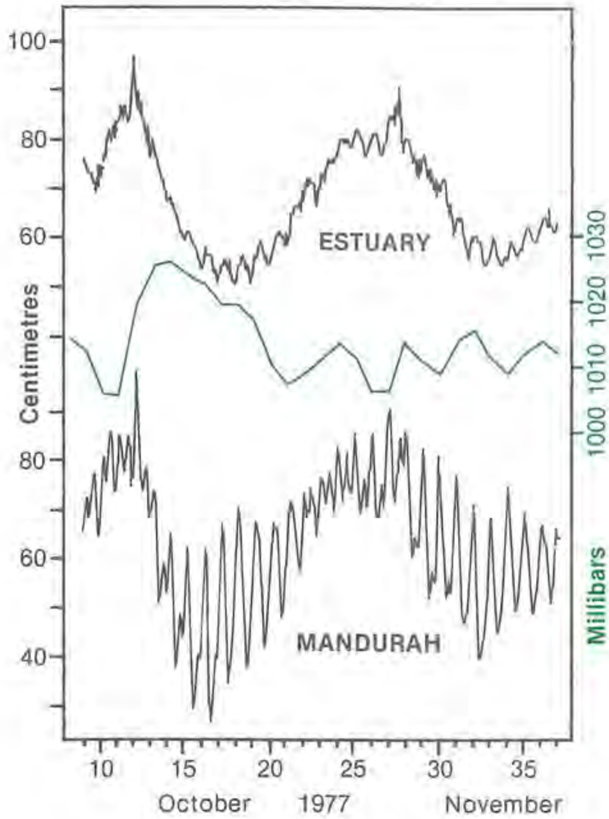
The catchment of the estuary is the region from which rainfall runoff flows into streams, rivers and drains to the estuary. The total catchment area of the Peel-Harvey estuary is 11,300km²; 2,200km² of this is on the coastal plain and 9,100km² on the plateau east of the Darling Scarp, most of it in the catchment of the Murray River.

Rainfall, evaporation and land use in the catchment all affect the quantity and the quality of water running into the estuary.

The coastal plain is mainly cleared for pasture for beef and dairy cattle. Soils are naturally deficient in phosphorus and superphosphate has been applied to agricultural land for the last 40 years.

East of the Scarp, the high rainfall forest region is State Forest, dominated by jarrah *(Eucalyptus marginata)* and marri *(E. calophylla)*. About 1700km² of this is in catchments of the Serpentine and Dandalup dams and the irrigation dams south of Waroona.

The inland agricultural region of the catchment, where rainfall is low and evaporation is high, is mainly cleared for grazing (cattle and sheep) and some cereal crops. River water from here is too salty for human use and so the Murray River and its tributaries on the plateau are not dammed.



Tide records from Peel Inlet & Mandurah

River Flows

River flows into the estuary are strongly seasonal; nearly 90% comes in the four months June to September.

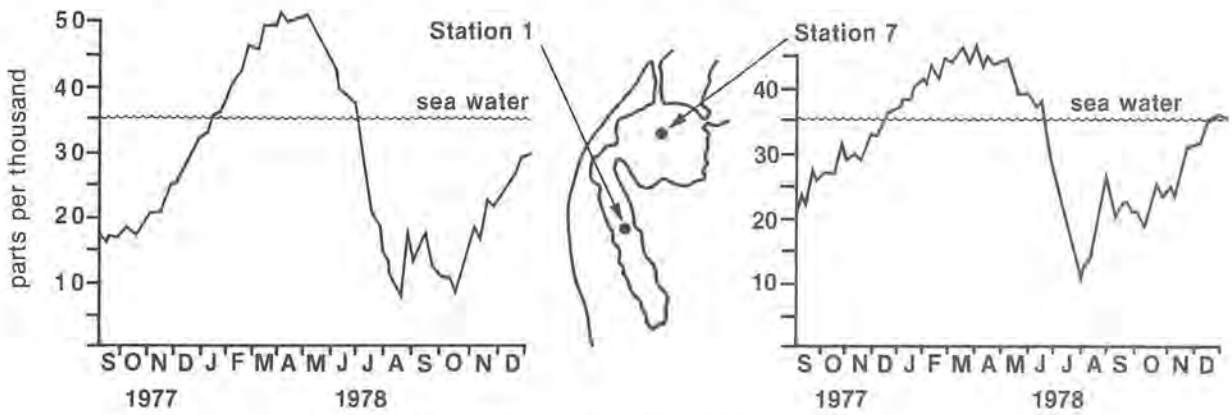
Flow in the Murray River has been measured since 1940. It is very variable, the annual flow ranging from $56 \times 10^6 m^3$ to $1{,}143 \times 10^6 m^3$. The period since the study of the estuary began in 1976 has been one of unusually low rainfall and river flow, and the Murray River was particularly badly affected by the drought in 1979. Flow in the river averages only 7.6% of rainfall onto the catchment (2% in 1979).

On the coastal plain, flows in the Serpentine and Harvey Rivers are less well documented, but the annual flow does not vary as much as in the Murray River. About 30% of rainfall on the Harvey catchment flows to the estuary.

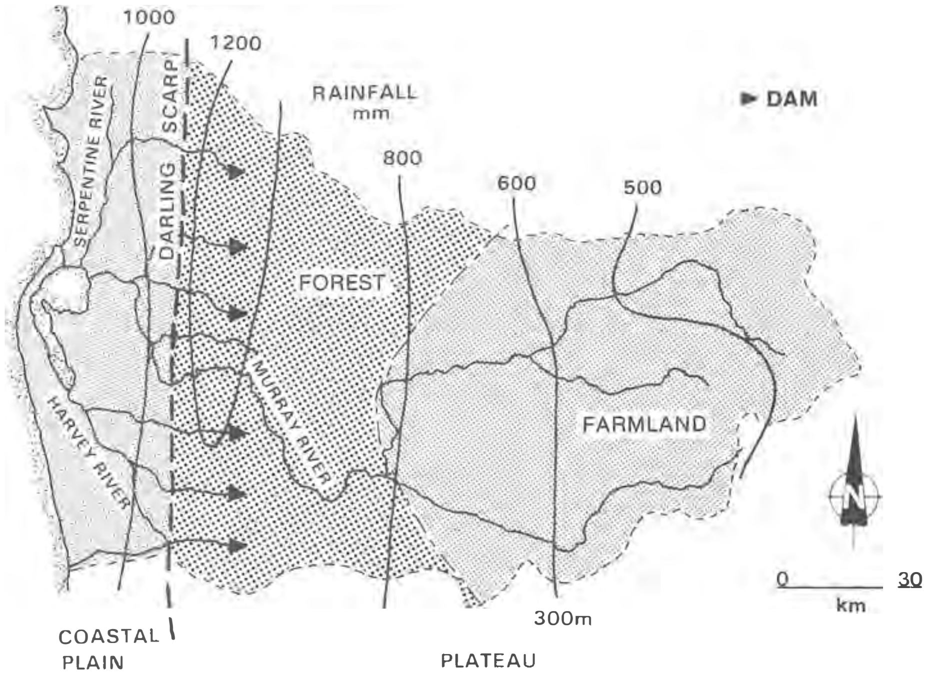
River flows to the estuary during the period of the study were estimated to be ($m^3 \times 10^6$):

River	1976	1977	1978	1979	1980	1981	1982
Serpentine	68	47	97	50	114	168	123
Murray	110	90	300	70	100	370	214
Harvey & Drains	77	102	230	130	260	330	230

Although the area of the Serpentine catchment is about the same as that of the Harvey River (and drains which discharge direct to the estuary) the density of drains is only half that of the Harvey catchment.



Seasonal salinity changes in the estuary



Catchment of the Peel-Harvey estuary

Where the nutrients come from

Nitrogen and phosphorus are the two most important nutrients needed by plants for their growth. An abundance of both can result in an eutrophic condition, such as exists in the Peel-Harvey estuary at the present time, and a shortage of either will limit plant growth even when there is plenty of the other.

Nitrogen comes to the estuary in river water, most of it from the Murray River (except in very dry years). Its source is probably mainly nitrogenous fertilizers and pasture legumes like subterranean clover which 'fix' atmospheric nitrogen. However, estuary water both gains much nitrogen from the atmosphere and loses it to the air. It would be very difficult to measure the quantities involved and impractical to try to stop it. Moreover, most of the time there is more than enough nitrogen in estuary water to support algal growth.

Phosphorus too comes in drainage from the catchments, 90% of it from cleared agricultural land to which phosphate fertilizers have been applied. At most, another 10% now comes from urban sources (sewage and garden fertilizer) and there are only insignificant gains from or losses to the atmosphere.

The amount of phosphorus coming to the estuary each year is roughly proportional to the volume of flow from rivers and drains of the coastal plain, so that in a dry year the input is relatively small and in a wet winter it is large. In 1979 the Harvey River contributed only 45 tonnes of phosphorus to the estuary but in 1981 it delivered 120 tonnes. In 1979 there was no *Nodularia* bloom; in 1981 the bloom was the worst we have experienced.

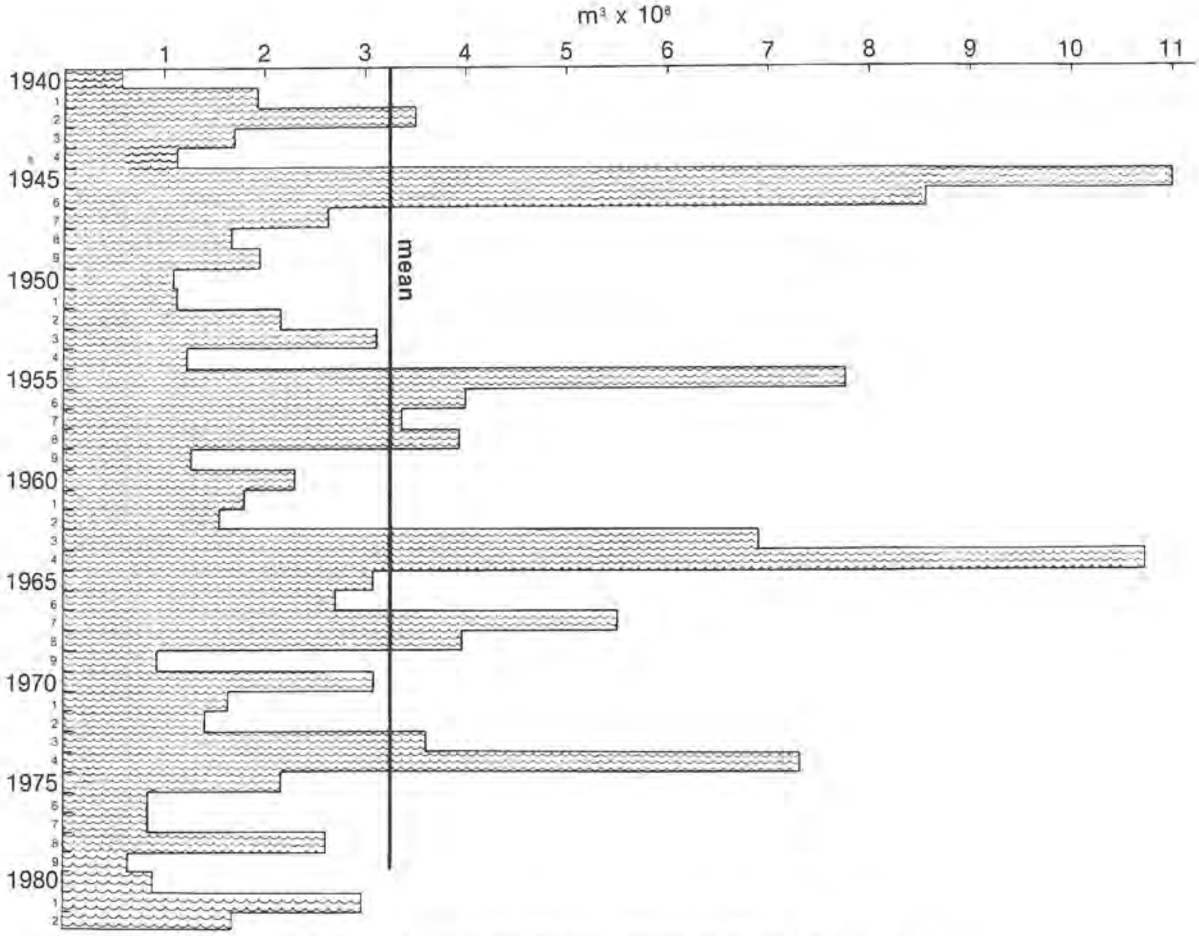
The 1983 input of phosphorus from the Harvey River is about 90 tonnes. The *Nodularia* bloom may be as bad as in 1981, but as explained in leaflet No. 1 the estuarine sediments now seem to be playing a greater role in the supply of phosphorus to algae.

The poor sandy soils of the coastal plain are naturally deficient in phosphorus and when it is applied as superphosphate 20 to 30% of it is lost to drainage.

More than half the phosphorus discharged to the estuary comes in at the south end of the Harvey Estuary, in water from the Harvey River and Mayfields Drain. In 1981, farmers in this catchment lost the equivalent of over $120,000 worth of superphosphate to fertilize Harvey Estuary.

The clay soils of the plateau, and smaller areas of clays and loams on the coastal plain, hold most of the phosphorus applied as fertilizer and little is lost to drainage. Only about 10% of phosphorus comes from the plateau.

Most of the time it is phosphorus that is in shortest supply in estuary water and it is for this reason, and because it would be almost impossible to reduce the input of nitrogen, that the emphasis is placed on controlling the supply of phosphorus to the estuary. Phosphorus levels can be lowered and this will reduce algal growth, despite the excess of nitrogen.



Annual flow in the Murray River at Hughes Bridge

Nutrient loss to the sea

Tides bring sea water into the estuary through the inlet channel and flush estuary water to the sea and it is important to know how much of the nutrients which come in river water is thus lost from the estuary.

Some of the water that runs on an ebb tide simply flows back on the next flood tide. Studies made in 1978 found that only 8 to 17% of water that entered on the flood tide was water that left on the previous ebb tide. Currents flowing along the coast rapidly carry the outflowing estuary water northwards most of the time.

In winter when the rivers are flowing strongly, estuary water is fresh and rich in nutrients. There is then a loss of nutrients to the sea. In the 1978 study it was estimated that there was a net loss of 100 tonnes of nitrate nitrogen in four days. Unfortunately the loss of phosphorus is much less because so much of the phosphorus brought into Harvey Estuary is trapped and stored there before the water reaches Peel Inlet and the sea.

In summer, when there is little or no river flow and high evaporation, more sea water enters the estuary than estuary water is lost to the sea. At this time the levels of dissolved nutrients in estuary and sea water are similar so tidal exchange does not cause a loss of nutrients available for plant growth.

However, nutrients are of course also lost with plant material when this goes to sea and during a *Nodularia* bloom considerable quantities of both nitrogen and phosphorus are lost in this way.

The effects of the hills dams

Some people have blamed the construction of reservoirs, and the reduced river flows from the hills catchments, for the estuary's algal problems.

There are several reservoirs in the catchment, the largest being the South Dandalup and Serpentine Dams. However, only a small part of the total catchment area (about 15%) feeds dams. The impact of the dams must be considered in the context of other changes which have taken place in the catchment.

The earliest dam was Harvey Weir, constructed in 1916. The most recently completed was the South Dandalup Dam in 1974. During this time, much of the coastal plain was cleared and drained for agriculture, creating over 1000 km of drainage canals. Much more of the rainfall runs off cleared land than from forested catchments and the drains increase flow to the estuary.

The reduced flow from the hills catchments has probably been more than compensated for by this increased flow from the coastal plain. It is of course true that the hills dams have reduced the flow of water that is poor in nutrients from the forested hills catchment, while the flow of water from agricultural land on the coastal plain has increased.

The hills dams do reduce the annual river flows into the estuary to some extent, but even if all the reservoirs in the Harvey catchment were removed, it is unlikely that this would increase the flow enough to benefit the estuary significantly. The flow to them is only about half the flow from the coastal plain catchment.

The Harvey Diversion Drain, which was dug in the 1930's, also diverts some water away from the river direct to the sea. It has been suggested that this water should be returned to the river to increase flushing of the estuary. The diversion drain only removes about 5% of the total inflow to Harvey Estuary and this water would have a negligible affect on flushing. Moreover, because the drain now acts as a flood relief measure the added flow from this source would overstrain the Harvey River drainage system, with serious implications for landowners in its catchment.
It would need a much more massive increase in flow to physically flush out the phosphorus. This is partly because river flows are only one factor affecting water movement in the estuary. Tides and wind mixing of the water are also important. Another reason is the way phosphorus is trapped and stored when the water moves through the estuary (as explained in No. 1 in this series).
River flow and the consequent nutrient input to the estuary is strongly seasonal. Although it is tempting to think of the winter river flow flushing the estuary and carrying the unwanted load of phosphorus out to sea, this is not the case.
Measurements in Harvey Estuary in 1983 showed that the plentiful phosphorus in river water entering the estuary was quickly grabbed by diatoms. By the time the water reached Peel Inlet, there was little phosphorus in the water and diatoms were abundant.
The dams are there to stay and other ways must be found to flush phosphorus to the sea if this should prove necessary in order to reduce the time during which nutrients can be taken up and stored in the estuary.

Dam	Date of Construction	Catchment area km^2	Total Storage Volume ($x10^6m^3$)	Average annual flow to dam ($x10^6m^3$)
Serpentine	1961	665	185	77
North Dandalup	1970	152	- (pipehead)	-
South Dandalup	1974	320	208	33
Waroona	1966	47	15	10
Drakes Brook	1931	-	2	4
Samson Brook	1941, 1960	65	9	14
Logue Brook	1963	39	24	15
Stirling	1948, 1958	251	57	64
Harvey	1916, 1931	181	9	47

The effect of the training walls

The ocean entrance to Peel Inlet has been a bone of contention with Mandurah residents since the early days of settlement in the South-West. The earliest river training work — a wall around Stingray Point, where the Peninsula Hotel now stands — was built in the 1880's in response to requests to the State Government to improve the entrance.

The problem is the shallowing of the bar, making it dangerous for the passage of boats. This happens because the rivers flowing into Peel Inlet and Harvey Estuary normally flow for only a short period each winter and tidal scouring alone is not sufficient to keep the bar open. As the tide comes in, sand is deposited in the inlet channel forming the inner bar. During ebb tides, some of the sand is carried back to the ocean, and is deposited on the outer bar. As the bar builds up, tidal exchange becomes restricted.

Before 1967, the bar sometimes blocked the entrance completely. The estuary then became stagnant for several months, the water level fell and water quality deteriorated with bad effects on the fishery. From time to time new training walls have been built or extended in order to keep the bar open and safe for the passage of fishing boats.

Between 1967 and 1969, following a detailed study of sand movements, the present two training walls were constructed. These, and periodic dredging, prevent the ocean entrance from being closed by sand drift. In addition, they have stabilized the channel and improved navigation.

Some people have blamed the training walls for contributing to the algal problem in the estuary, believing that they interfere with nature and reduce flushing. In fact, they improve tidal exchange, especially over the summer months. Further improvement of the channel would increase flushing of the estuary, and hence loss of phosphorus to the ocean. However, doubling the flushing rate would only increase nutrient losses by about 15% and to do this it would be necessary to double the size of the channel.

Improving the channel, and other more effective ways to increase flushing, are among the management options currently under review.

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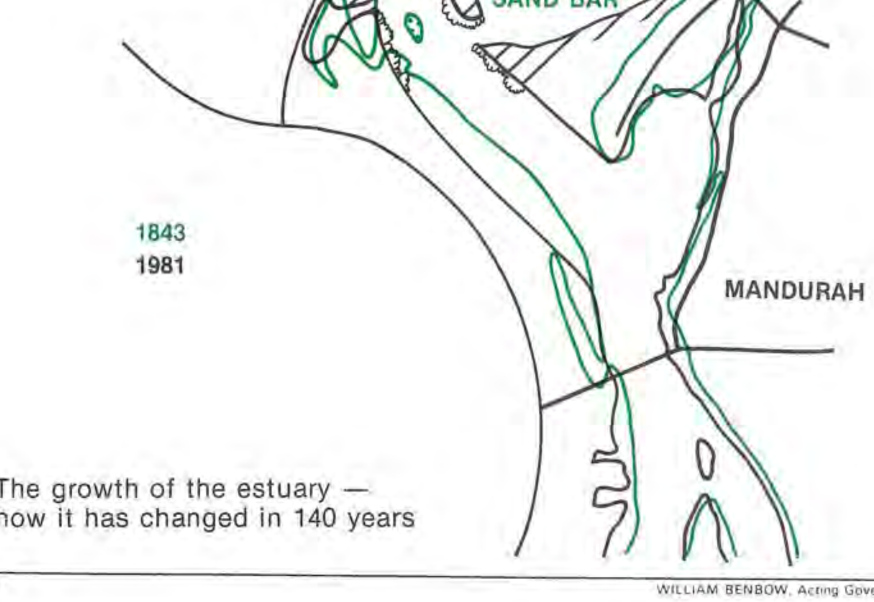

The growth of the estuary — how it has changed in 140 years

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WILLIAM BENBOW, Acting Government Printer, Western Australia

PEEL – HARVEY ESTUARY PROGRESS

Department of
Conservation and
Environment

BULLETIN No. 146

NO 5
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1984

MANAGING THE ALGAL BLOOMS : REDUCING THE PHOSPHORUS INPUT TO THE ESTUARY

Soil testing helps farmers to determine the best fertilizer strategy.

The aim of management

The algal problem in the Peel-Harvey estuary has resulted from a great increase in the amount of nutrients, especially phosphorus, carried into the estuary by rivers and drains. The phosphorus comes mainly from superphosphate which has been applied to the phosphorus-deficient soils of the coastal plain over the past forty years.

One approach to managing the algal blooms, perhaps the most important because it attacks the cause, is to lower the nutrient levels in the estuary by reducing phosphorus input at its source.

The source of the phosphorus

At least 90% of the phosphorus comes from land cleared for agriculture, most of it from the coastal plain.

The soils are deficient in phosphorus and this is supplied by the application of superphosphate. (Superphosphate contains 10% phosphate and also sulphur, 11%). Without fertilizer there could not be a viable and productive agriculture. For example, fertilised paddocks can carry about ten times as many cattle per hectare as unfertilised land.

However, rain washes much of this applied phosphorus from the land into drains and rivers which flow to the estuary. In 1981, farmers in the Harvey River — Mayfields Drain catchment lost the equivalent of 16 000 bags of super into the estuary. Between them they spent $120 000 to fertilize a crop of blue green algae.

What causes the phosphorus loss?

The amount of phosphorus lost from the land depends on a number of factors : the amount of land cleared and the effectiveness of drainage from it; the nature of the soils and the type of farming; the amount and kind of fertilizer used and the time at which it is applied (before, during or following the rains).

The amount of phosphorus entering the estuary also depends on winter rainfall. In years of heavy rainfall more is washed in than in dry years with little river flow. There were no algal blooms in the estuary in the dry years 1975-77 and 1979.

Soil types

Different types of soils vary in their ability to "bind" or hold phosphorus.

The laterite and clay soils of the Darling Range hold most of the phosphorus applied as fertilizer. Even though phosphate fertilizers are used extensively, only about 10% of the phosphorus entering the estuary comes from the plateau. The heavy soils on the coastal plain, the loams and clays, also hold most of the phosphorus and only release about 5% of that applied to drainage. On the other hand, the sandy soils of the coastal plain are less able to bind the phosphorus, and much of the superphosphate which is applied to these phosphorus-deficient soils is washed away. These soils are of two main types : 'duplex' soils with about 30cm of sand over clay and the 'deep grey sands' where there is about 2m or more of sand overlying 'coffee rock' (Figs 1 and 2).

During the last 40 years the area of land cleared and cultivated has increased progressively and the drainage system has been greatly improved. It was only in the 1970's that big areas of the deep grey sands were cleared and drained.

Much of the catchment of the Harvey River and its associated drains consists of these deep grey sands and duplex soils, and this is the largest source of phosphorus entering the estuary. In 1978, when the Harvey River contributed only 37% of the total flow into the estuary, it carried in 60% of the phosphorus. The following low-rainfall year, when the Murray River flowed poorly, the Harvey accounted for 76% of the phosphorus.

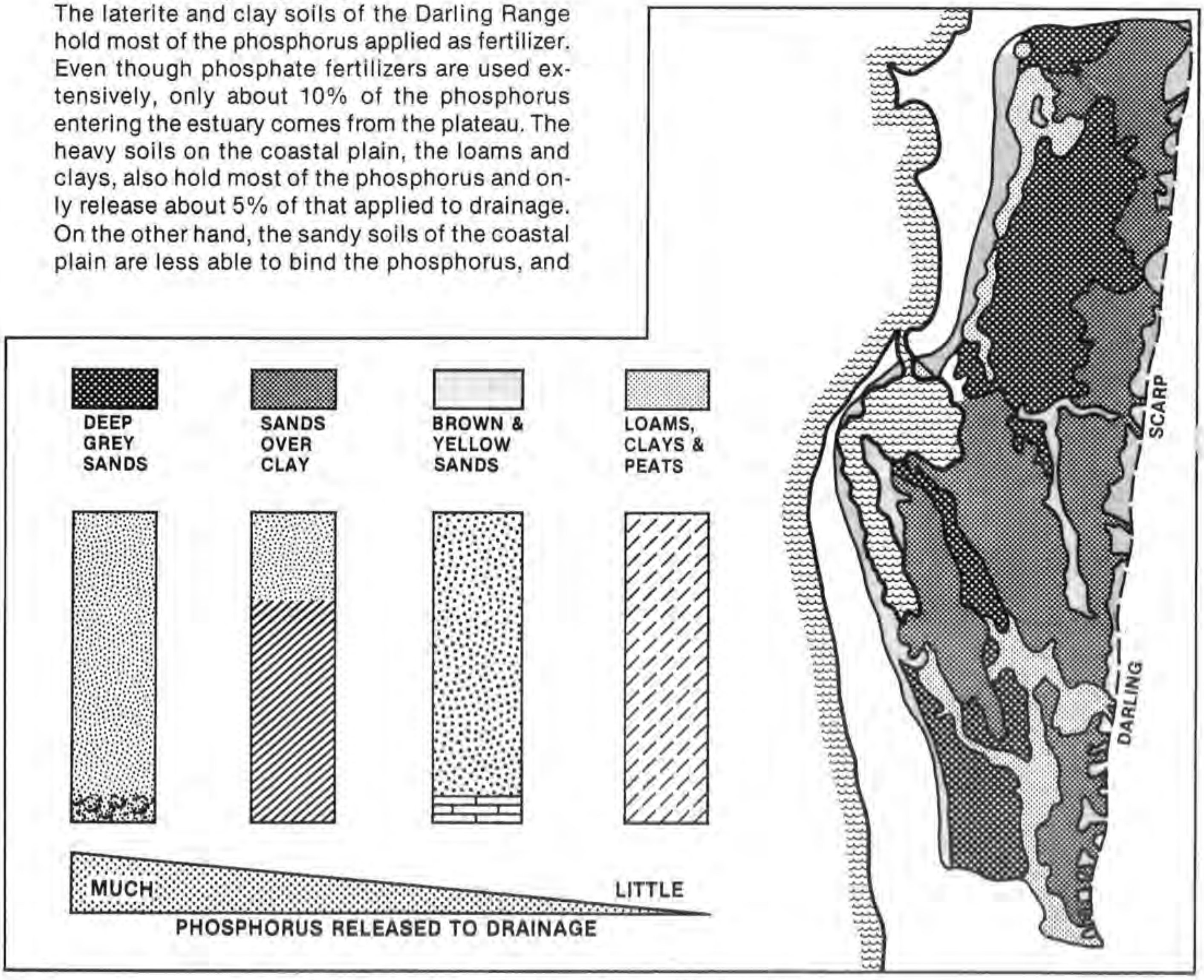

Figure 1. Soil categories on the coastal plain catchment

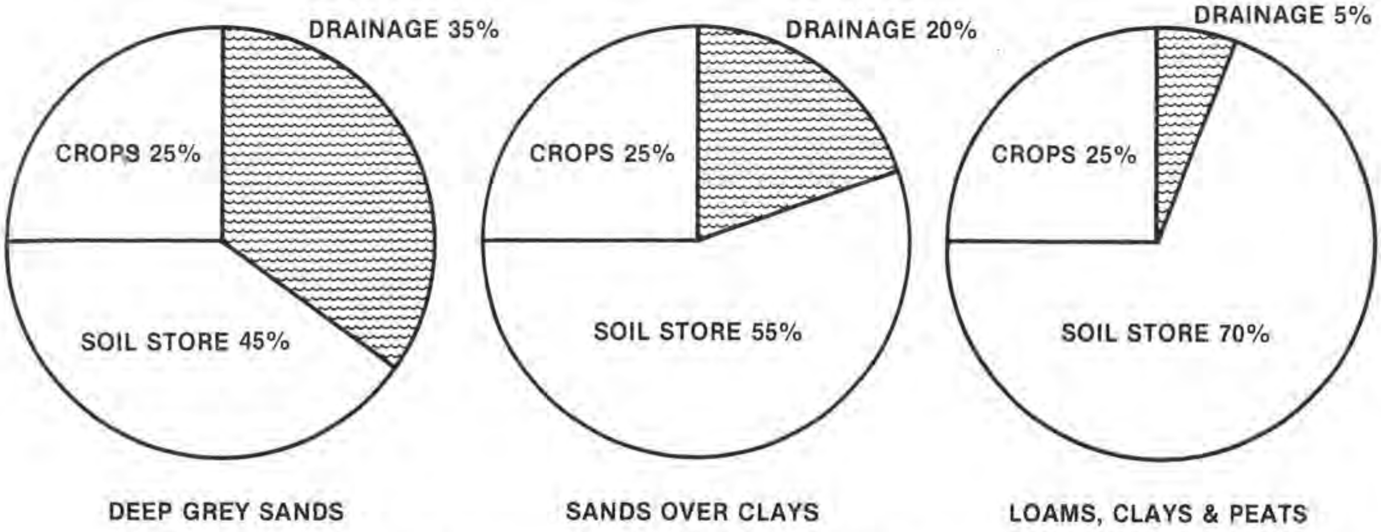

Figure 2. The fate of the applied phosphorus. (The figures are approximate only)

As well as fertilizing the estuary, the phosphorus runoff represents a costly loss to farmers. For example on the deep grey sands in the Meredith Drain Catchment, only 25% of the phosphorus applied each year is used by the pasture. Almost half (40 to 50%) stays in the soil and groundwater store, and about 35% is lost to drainage (Fig 2).

How can the phosphorus loss be reduced?

Fertilizer strategies

One way to reduce the loss of phosphorus is to improve the way in which the land is fertilized. Traditionally, phosphorus has been applied to soils in the Harvey River catchment at the rate of about 180 kg of superphosphate to the hectare (one bag to the acre), around the break of the season. Heavier dressings are applied to irrigated paddocks.

This has continued for many years and has resulted in phosphorus being applied to many paddocks which no longer need to be fertilized annually.

Current research is helping farmers to apply only the amount of phosphorus needed to maintain production, and to supply it in a less soluble form so that less is washed away on sandy soils.

An extension programme to bring the results of this research to farmers began in 1982. So far it has concentrated on about 200 farms on deep sands and sand over clay areas in the Harvey estuary catchment — the source of much of the phosphorus entering the estuary. The programme will eventually be extended to the whole coastal plain catchment.

The research is a joint effort by the Department of Agriculture, Department of Conservation and Environment, C.S.B.P. and the Government Chemical Laboratories.

How much fertilizer?

The amount of fertilizer needed to maintain production can be determined by soil testing. Soil samples are analysed to measure how much phosphorus there is in the soil for plants. The farmer can then tell how much needs to be applied to give him an economic crop.

Soil tests in the Harvey estuary catchment have shown that despite phosphorus being washed away, soil reserves have gradually built up over the years. Once the soil reserve — the "super bank" — has built up, less fertilizer is needed to maintain high yields.

Over 90% of the duplex soils, and nearly half the deep sand paddocks which were tested in 1983 required no added phosphorus for at least one year, and many not for a number of years.

Many farmers could at least halve the amount of phosphate applied and still maintain production providing sulphur and potassium levels are kept up. This would represent big savings for farmers.

Fertilizer cannot be left off indefinitely or the 'super bank' will run down. The goal is to build up the soil reserves (as most farmers have already done) and then apply only enough phosphorus to maintain production, thus reducing wastage of fertilizer to the estuary.

Research is improving fertilizers

A slow-release superphosphate — "coastal super", was developed by the Department of Agriculture and C.S.B.P. to supply phosphorus in a less soluble form. Farmers co-operated well in trying out the new fertilizer and in 1983 three quarters of the farmers on deep sands, and a quarter of those on duplex soils in the Harvey River catchment used "coastal super".

Experiments showed that paddocks fertilized with coastal super lost less phosphorus to the estuary, but there were still some problems.
Sulphur, which is essential to plants, does not build up in sandy soils and has to be applied each year by the amount supplied by one bag of super to the acre. Superphosphate (or coastal super) is a convenient but expensive way to apply sulphur, once the phosphate bank has built up. Another source of sulphur is gypsum — a waste product from the C.S.B.P. factory, but farmers often found separate application of gypsum inconvenient.
For best effect gypsum has to be applied in spring, as it is rapidly washed from the soil by rain.
A new fertilizer developed by the Department of Agriculture and C.S.B.P. — "new coastal super" — solves the sulphur problem. New Coastal Super supplies both fast and slow-release sources of phosphorus and is enriched with sulphur. It also has better storage and handling qualities than the old coastal super.
This is now being sold for use on coastal plain soils instead of superphosphate. The result will be better farming practices as well as a cleaner estuary.

Phosphorus losses from heavy soils

Clays and loams are able to bind much more phosphorus than sands. Nevertheless, phosphorus can be lost by surface runoff if heavy applications of superphosphate are followed by heavy rains.
Soils surveys show that most farmers are applying considerably more phosphate than they need to maintain production. Since sulphur reserves are good in heavy soils, the solution here is simply to apply less ordinary superphosphate.

Will better fertilizer strategies help the estuary?

Experiments comparing phosphorus runoff from unfertilized paddocks with losses from areas fertilized with superphosphate and with the 1983 coastal super have shown that about a third of the phosphorus washed from sandy soils comes from fertilizer applied that year. The rest comes from the phosphorus store in the soil — the farmer's 'super bank'.
This means that if losses of freshly applied fertilizer are reduced (by using slow-release fertilizers and applying only enough to maintain production), the amount of phosphorus running into the estuary should drop by the same amount — about a third.
These experiments were part of a study by the Department of Conservation and Environment in conjunction with the Soil Science Department of the University of Western Australia, the Public Works Department, C.S.I.R.O.'s Division of Groundwater Studies and the Department of Agriculture. These studies are helping scientists to understand the sources and amount of phosphorus fertilizing the estuary, so it can be reduced.
Better fertilizer practices will substantially reduce phosphorus losses to the estuary as well as improving agricultural practices on the sandy soils of the coastal plain. Reducing the phosphorus input to the estuary by 30 to 40% would be a significant step towards improving the condition of the estuary but may not, on its own, solve the algal problem.
It may be possible to achieve further long-term reduction of phosphorus loss to drainage by other methods, and these are discussed below.

Bauxite residue may help

Another way in which it may be possible to reduce the loss of phosphorus from sandy soils is to make them more like the loamy soils near the Darling Scarp. Residue from Alcoa's alumina refineries has the potential to do this and so both help the estuary and greatly increase pasture production on the deep grey sands.
Alcoa, in conjunction with the Department of Agriculture and the Department of Conservation and Environment, is conducting trials to test this potential and this has already aroused the interest of farmers.
Alcoa currently disposes of about eight million tonnes (dry) of residue in specially built impoundments each year. The residue left after alumina extraction consists largely of Darling Range soil, which has been crushed and treated with caustic soda. The residue is separated into a sand fraction and a fines fraction, commonly known as 'red mud'. It is this fine fraction which can be filtered and neutralized with gypsum (another waste product, from C.S.B.P. fertilizer manufacture) to produce a loam suitable for spreading and mixing into the sands. At this stage it bears little resemblance to the original 'red mud'.
This loamy residue has a high capacity to retain phosphorus, so less fertilizer will be lost to the estuary from sandy soils treated with the residue. In addition, it increases water retention. This means that on sandy soils there is the potential to increase pasture production — a bonus to farmers who are faced with cultivating the ridges of dry grey sands.
Water also penetrates more evenly into treated sand and hence germination is more even. Trials have shown that the second season's germination is better on sands treated with the residue. This means that a dense legume pasture is easier to maintain on the treated soil.

Trials are underway to determine the best application rates and fertilizer requirements. These trials will be extended over a larger area and will include sand over clay soils as well as the deep grey sands.
Other experiments are designed to find out which plants grow best in the residue-treated sands and, more importantly for the estuary, how much phosphorus is retained.
Another important area of research is to ensure that there are no harmful side effects. Water leached from residue-treated soils is being monitored to check that no harmful chemicals enter the groundwater. Plants growing on treated areas are also analyzed. So far, results have shown no adverse side effects.

Measuring pasture growth on soils treated with amended bauxite residue in ALCOA's field trial area.

Swamps can help the estuary

Research being carried out in the Botany Department at the University of Western Australia has shown that artificial wetlands could be a useful and practical way of removing nutrients from concentrated sources, such as piggeries and feedlots.
Pigs produce a waste load of 3kg of phosphorus per pig each year. Pollution from piggeries, and other operations which produce nutrient-rich liquid wastes, can be reduced by collecting the wastes in settling ponds and diverting the overflow through artificial wetlands. The plants remove much of the phosphorus before the water reaches the natural drainage system.
Although such point sources now contribute less than 10% of the phosphorus input to the estuary, this type of industry is expected to increase and make a greater nutrient contribution in the future, especially in the Serpentine catchment. Artificial wetlands could play an important part in treating their effluent.
Unfortunately, similar treatment of runoff from agricultural land by establishing artificial swamps along agricultural drains or at their outlets does not look promising. The high flow rates in the drains would give the plants too little time to take up the phosphorus, and enormous wetland areas would be needed.

Changes in current land use

Clearing the land for pasture has involved removing deep-rooted native plants that need very little phosphorus and replacing them with shallow-rooted grasses that need heavy phosphate dressings. It may not be a practical proposition to turn back the clock and revert to native vegetation, but there are deep rooted crops which need little phosphorus and a lot of water, so that little of either is lost to drainage.

The economic potential of pines, eucalypts for wood chipping, tree lucerne and other crops is being examined. Some such crops may prove to be profitable on the poorer soils, from which phosphorus loss rates are highest.

How long will it take to reduce the phosphorus input?

These measures — soil improvement with bauxite residue, the treatment of effluent from point sources, and changes in land use can, in the long-term, help to reduce the amount of phosphorus draining to the estuary, but it is changes in fertilizer practices that will have the main impact.

Field trials in the Harvey River catchment have shown that the recommended changes can reduce phosphorus input by an estimated 30 to 40% within 3 to 5 years. How quickly this reduction can be achieved will depend on the continued co-operation of farmers in implementing the changes in fertilizer use, throughout the coastal plain catchment of the estuary.

Will reducing phosphorus input solve the algal problem?

In 1979 there was no *Nodularia* bloom. In every other year since 1978 there have been blooms. 1979 was a dry year and only 40 tonnes of phosphorus came into Harvey Estuary; 1981 was a year of above average river flow and 120 tonnes entered the estuary.

It is evident that there would have to be a considerable reduction in phosphorus input to ensure that there were no more *Nodularia* blooms. Even if no fertilizer was used on farms on the coastal plain it would probably be many years before input was sufficiently reduced.

This is because 60 to 70%, perhaps more, of the phosphorus lost each winter comes from the store which has built up in the soils over many years. About one third comes from fertilizer applied in the current year.

Improved fertilizer strategies, and other methods to reduce phosphorus input, are vital to improving the condition of the estuary. It may not be possible to achieve a sufficient reduction in a reasonable time for this to be the total answer to the algal problem.

The answer for the estuary will probably involve a combination of management measures to reduce phosphorus input to the estuary, to remove the accumulated weed (see Bulletin 146 no.2), and to increase the loss of phosphorus from the estuary to the sea. (This will be the subject of another pamphlet in this series).

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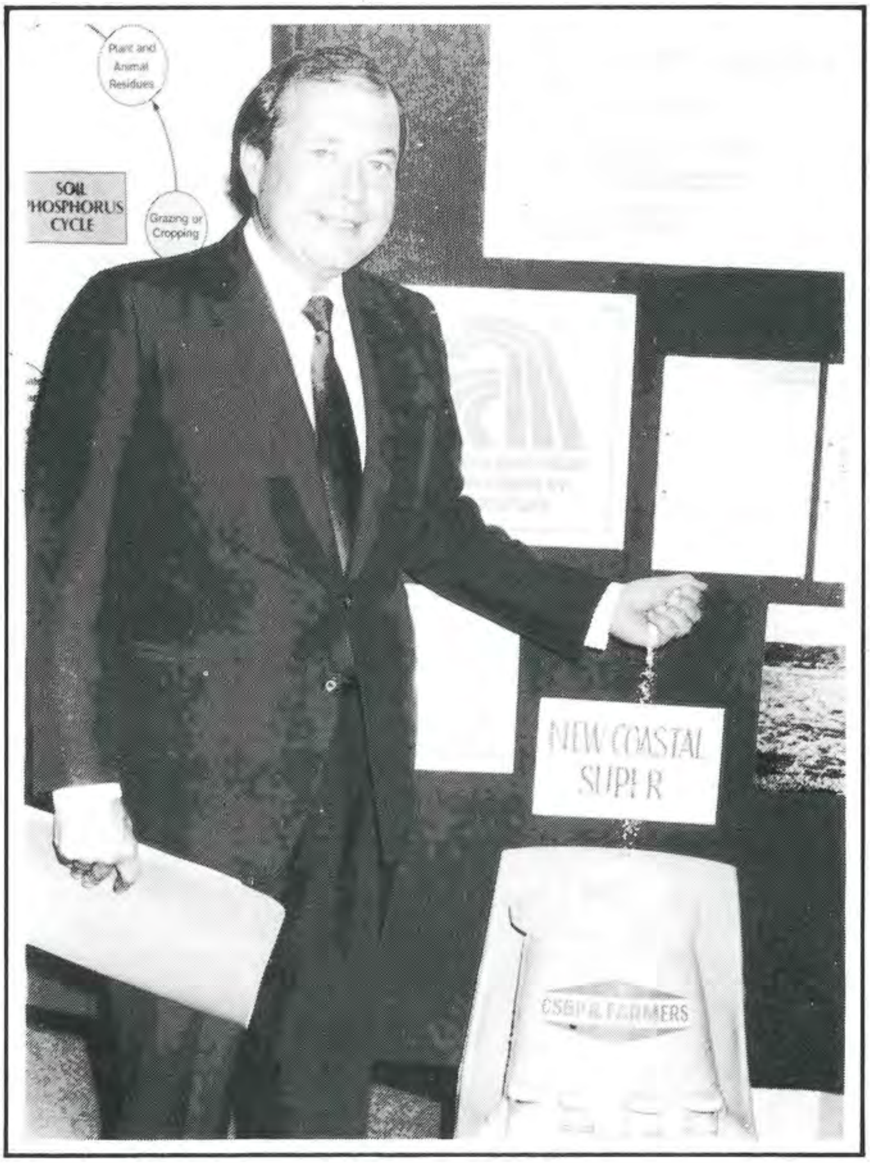
PEEL – HARVEY ESTUARY PROGRESS

Department of
Conservation and
Environment

BULLETIN No. 146

NO 6
MARCH
1984

ASSESSING THE MANAGEMENT OPTIONS



The Hon. Brian Burke M.L.A., Premier of Western Australia.

How best can the algal problems of the estuary be minimised, while at the same time maintaining productivity both of the fishery and of agriculture on the coastal plain?

Suggestions as to how the estuary should be managed have come from many sources — from the Press, from the general public and from the Peel Inlet Management Authority, as well as from scientists and engineers on the study team. All ideas were carefully examined by a group at the Centre for Water Research at the University of Western Australia.

The detailed evaluation was done in close collaboration with officers of the Public Works Department, the Department of Conservation and Environment, Department of Agriculture, Government Chemical Laboratories, and other members of the Peel-Harvey Study group from the University and CSIRO.

Goals of management

The first step in any management is to define the goals — how do we want the estuary to be in the future? This is not as simple as it sounds because in many cases there are conflicting needs and interests. There is no way we can just turn back the clock to the days of no algae and clean beaches — the changes have been too great. Most people want clean beaches, free from decomposing algae, clear water without the green *Nodularia* scum, and no more foul smells. They want lots of fish, crabs and prawns.

In some respects we can't have our cake and eat it too — there have to be compromises. For example, the large green algae in Peel Inlet have benefited the fishery by sheltering the fish from predators and by providing a habitat for the many small animals on which the fish feed. It may not be possible to have both completely clean, weed-free water and plentiful fish. Similarly, it is not possible to maintain productive agriculture on the coastal plain without fertilizing the paddocks, and this inevitably results in the loss of some phosphorus to drainage.

Any management measure will alter the character of the environment, in ways that are not always easy to predict, and care must be taken to ensure that any management strategy adopted will do less damage to the environment than is caused by the present algal problems.

SPECIFIC GOALS OF MANAGEMENT FOR THE ESTUARY ARE THEREFORE:

1. LARGE GREEN ALGAE SHOULD NOT CAUSE FOULING OF BEACHES NEAR POPULATED AREAS.
2. *NODULARIA* BLOOMS SHOULD NOT OCCUR MORE THAN ONCE IN FIVE YEARS.

THESE GOALS SHOULD BE ACHIEVED WITHOUT FURTHER DAMAGE TO THE ESTUARINE ENVIRONMENT AND IF POSSIBLE WITHOUT LOSS OF PRODUCTION OF THE ESTUARINE FISHERY AND OF AGRICULTURE ON THE COASTAL PLAIN.

Assessing the management options

Every suggestion for managing the estuary has been carefully assessed with respect to its cost, technical feasibility, whether it would improve the condition of the estuary, and whether it would have undesirable side effects.

The answers are not always obvious, and careful collection and analysis of data is needed to predict what a certain course of action will achieve.

Over a hundred options have been considered. Some were quickly discarded because they would not achieve sufficient improvement in the condition of the estuary, or would have unacceptable side effects.

For instance, explosive charges are sometimes used to control blooms of blue-green algae in reservoirs in the United States. A preliminary evaluation revealed that it would cost about $200,000 in explosives alone to treat a bloom in Harvey Estuary. The explosion would cause a massive fish kill, and the algae would be back within 3 days.

Other methods of **directly attacking the algae** were also investigated. For example, biological control by introducing weed-eating fish was considered, but the history of introductions to Australia has been disastrous, not least the introduction of exotic fish. In any case it is most unlikely that any fish would eat the *Nodularia*. Control by pathogens (fungi, bacteria or viruses) was investigated, but no suitable organisms have been found.

Another possible way of attacking the algae is the use of chemicals — algicides. These, like herbicides, poison the plants or interfere with their growth. Some common algicides, like copper sulphate and other copper compounds, were rejected because they are too toxic, especially to fish, and can build up in the food chain. There may be chemicals which do not have such side effects, but they cannot be used in the estuary without extremely careful evaluation of their usefulness and possible effects. One such compound is being tested in the laboratory.

Other methods investigated involve **making conditions less suitable for the algae to grow** and cause blooms.

For example, plants require light for growth and the light could be greatly reduced by mixing tannins, or other chemicals, into the water. This happens naturally in the swamps of the coastal plain. If enough chemical was poured into the estuary to keep pace with its loss to the sea this might work but, as with the algicides, it would do nothing to prevent the algal problems. That will only be done by **reducing the amount of phosphorus in the estuary.** (see Bulletin 146 No. 5)

One proposal for reducing the phosphorus was to divert the Harvey River and Mayfields Drain flow — the largest source of phosphorus — away from the Harvey Estuary to the sea. This would not be as simple as it sounds, as it would involve tunnelling through the limestone of the coastal hills.

Several methods were proposed, including diverting the nutrient-rich water to the sea through the coastal lakes. This would require a barrage at the south end of Harvey estuary (to create a storage reservoir and prevent the water flowing into the estuary), and a series of channels to divert the water to Lake Clifton, Martins Tank, Lake

Preston, and then to the sea via the Myalup Diversion Drain or Leschenault Inlet. Another possible plan involved a barrage at Herron Point Ford and pipelines, channels or tunnels directly to the ocean.

These ideas were rejected when assessment showed that not only would they be very costly to implement, but they would be harmful to the fishery and cause severe environmental problems. The barrage would necessitate resumption of about 1400 ha of farm land and nature reserves for the storage reservoir, the water of which would be severely eutrophic. If the flow was channeled through the coastal lakes, they too would become eutrophic, spreading the present problems of the estuary over a wider area.

Another idea which was suggested early in the study involved dredging the sediments in Peel Inlet. Separate proposals involved removal of the nutrient-rich top 100mm of sediment from the estuary floor, deepening the marginal shallows, and deepening areas where the large green algae grow.

Dredging in fact offers little benefit to the condition of the estuary, especially while the phosphorus continues to flow in, and is an extremely expensive option. For example, dredging to remove the top 100mm of sediment in Peel Inlet alone would cost over $17 million, and take 10 years for one dredge to complete. It would have to be repeated every 5 to 10 years.

All the dredging options would cause damage to the environment, especially to the fishery. Dredging the marginal shallows would create a pool for decaying algae. Deepening the areas where the algae grow would reduce their growth, but at the cost of destroying the habitat of juvenile fish, and disrupting the food chain in the estuary.

Detailed evaluation

Other options were more promising and these were subjected to a detailed evaluation — is the idea practical?; how long will it take for the desired effect to occur?; what other side-effects might there be; what will it cost?

Detailed assessment reduced the number of suggested approaches from about 120 to about 9.

Predicting the outcome

Careful assessment of all the options will enable the decisions about management of the estuary to be made on the soundest information available.

It will not be possible to predict precisely the outcome of a management strategy any more than it is possible to accurately predict rainfall and the volume of river flow. Changes in the biology, for example the types of algae dominating in the estuary, are other unpredictable factors. It will be important to watch the effectiveness of management procedures to give feedback and allow adjustments to be made in the light of year by year changes in the condition of the estuary.

Studies since 1976 have provided a valuable basis for making decisions. Some of the data are still inadequate and studies are now underway to provide the necessary information. For example, it is essential to have accurate data on river flow and how it varies. There was no reason to measure the flow in the Serpentine and Harvey Rivers before the Peel-Harvey Estuarine System Study began. This means that there are no long-term records of flow. Only since 1982 have we had good flow data for the Harvey River, and for the Serpentine there are still only estimates of the total flow. In addition, the period since the study began has been one of unusually low rainfall and river flow, and we can do little more than speculate what will happen in a flood year like 1945. As was shown in leaflet 5, the size of the algal blooms depends largely on the amount of phosphorus entering the estuary and this in turn depends on the volume of river flow.

Variations in river flow are important in planning engineering options, such as new channels to the sea which have to be able to cope with exceptional, as well as "average" years. Some studies may seem to take a long time because it is necessary to take measurements over several seasons, but they are well worthwhile in preventing costly mistakes and damage to the environment, which could be even worse than the current algal blooms.

The management decision

Decisions about management do not lie with the scientists, whose role it is to provide the facts and interpret them. The decisions lie with the Government, on the basis of recommendations from the Policy Advisory Group, which consists of heads of relevant Government Departments, and the Peel Inlet Management Authority.

The results of all the studies to date were presented at a Symposium in November 1983, and recommendations were made to the Government.

In February, 1984, the Premier, Mr. Burke, announced that Cabinet had adopted the major recommendations, and launched Phase 3 of the project. Mr. Burke announced that:

> **The fertilizer programme** (see leaflet No.5), **which began in 1983, is to be extended to the entire coastal plain catchment of the estuary (200,000ha).**

A new improved superphosphate has been developed. This slow-release fertilizer is suitable for use on the sandy soils of the coastal plain.

It will reduce phosphorus runoff into the estuary, whilst maintaining productivity of the soil.

The fertilizer management programme will be supported by a team of 23 people employed under the Community Employment Programme to enable the Department of Agriculture to provide a free soil testing service and monitoring programme throughout the coastal plain catchments.

The results of the phase 2 studies have shown that the fertilizer modification programme, by itself, is not enough. A project team will further evaluate about 9 options which have been shown to have the potential to complement the fertilizer modification programme. The project team will report to the Government within 6 months.

The management options

The options include further measures to reduce phosphorus input to the estuary:

- the use of artificial wetlands to soak up phosphorus from concentrated sources, such as piggery wastes;
- soil treatment with suitably treated bauxite residue to improve the phosphorus and water holding capacity of sandy soils;
- changes in current land use.

Other options would improve the exchange of water with the ocean (flushing) and hence increase loss of phosphorus to the sea. These include:

- enlarging the Mandurah Channel;
- cutting a new channel from Harvey Estuary to the sea.

Direct attacks on the algae themselves, whilst not preventing the problem, can help to keep the estuary clean in the short-term.

- Weed harvesting will continue, with increased funds to allow for longer hours of operation if required;
- the possible use of algicides to kill the *Nodularia* will be investigated.

The project team will assess the effectiveness, costs and potential adverse effects on the estuarine environment, to enable the Government to decide which of these options should be adopted. The Premier stressed the importance of identifying all the effects of any measure before it is implemented.

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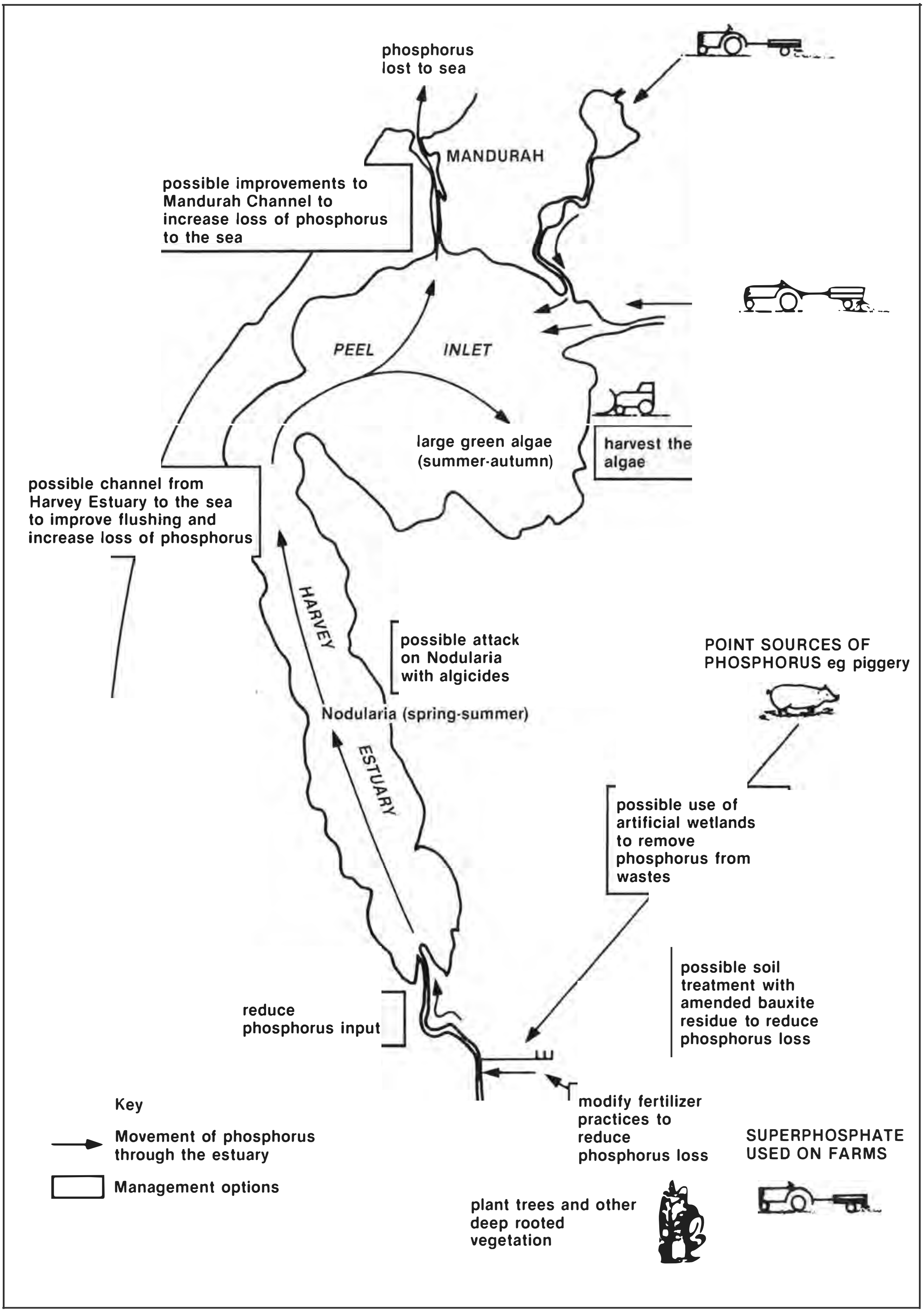


The management options

PEEL – HARVEY ESTUARY PROGRESS

Department of
Conservation and
Environment

BULLETIN No. 146

NO 7
MAY
1984

MANAGING THE ALGAL PROBLEM: THE PREFERRED STRATEGY

Launching Phase 3 of the Peel-Harvey Estuarine System Study in February 1984, the Premier, Mr. Burke announced that a report summarizing the findings and recommendations of the studies to date would soon be released.

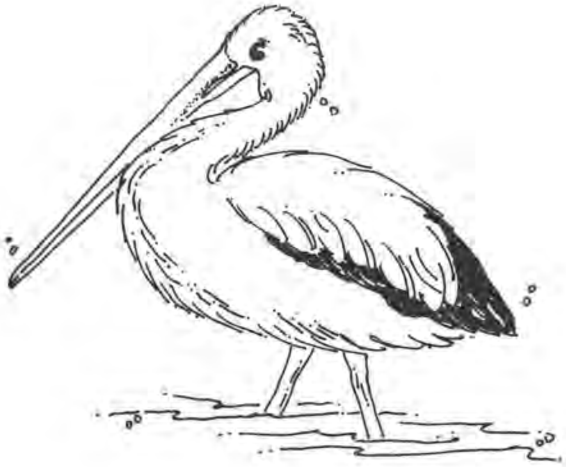
Copies of the report, "Management of Peel Inlet and Harvey Estuary — Report of research findings and options for management", are now available from the Department of Conservation and Environment in Perth and from the Peel Inlet Management Authority in Mandurah. The report briefly reviews the history, nature and causes of the estuary's algal problems, and goes on to consider what should be done to clean up the estuary — what are the management objectives and how and when can they be achieved? It then outlines the management recommendations which have been made at this stage, and the further work which still has to be done before final recommendations are made to the Government early in 1985.

As explained in Leaflet No. 6, a large number of potential management measures were carefully assessed in 1983 and many of them were rejected.

This leaflet deals only with the "preferred strategy" — the combination of management measures which, at this time, is considered to offer the best solution to the estuary's problems, and also with some supplementary measures which require further assessment.

Management objectives

The principal objective of a management programme for the solution of the estuary's algal problems is to reduce the algal nuisance to acceptable levels — levels at which *Nodularia* blooms are only infrequent events and the beaches are free of rotting weed most of the time. Ideally, this should be accomplished without further damage to the estuarine environment and without causing any loss of production of the estuarine fishery or of agricultural production on the coastal plain.



Management measures

The report describes a number of management measures which can achieve these objectives by using a combination of control and preventive measures.

Control measures attack the algae themselves, for example by harvesting the algae and using tractors to prevent weed accumulating and decomposing on the beaches. These methods help to relieve the unpleasant symptoms of the problem, but do nothing to prevent it.

Preventive measures attack the cause of the problem — in this case the eutrophic, or nutrient enriched, state of the estuary. Preventive measures include both ways to reduce the amount of phosphorus running into the estuary and action to increase phosphorus loss to the sea, so as to reduce the amount available to fertilize algae in the estuary.

The preferred strategy

It is clear from the studies which have been made that there is no single, practicable measure which by itself will reduce the phosphorus levels sufficiently to achieve the management objectives.

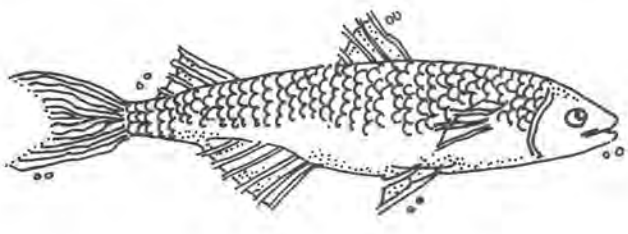
A combination of measures has therefore been developed, which will keep the beaches clean in the short term and, in the longer term, will greatly reduce both the weed problem and the annual blooms of *Nodularia*. The report does, however, stress that because an excess of nutrients has built up over many years, both in the coastal plain soils and in the estuary sediments, even this combination of measures cannot be expected to clean up the estuary in less than three to five years.

This combination of measures — the "preferred strategy" described in the reports — consists of:

- harvesting the large green algae, the weed, in Peel Inlet;
- modifying agricultural practices on the coastal plain to reduce phosphorus input to the estuary;
- improving tidal exchange to increase the loss of nutrients to the sea by flushing.

Weed harvesting

Two weed harvesters are used to collect the large green algae where they grow, mainly in water over half a metre deep. This reduces the amount of algae being washed ashore to rot on the beaches near populated areas, especially at Coodanup and Falcon. (See leaflet No. 2). Algae which accumulate on the shore are collected by tractors equipped with rakes, and trucked away and dumped. Two new front-end loaders were purchased in May, to replace machines worn out by constant exposure to the harsh conditions. These measures should be able to keep beaches near residential areas free from weed for about 85% of the time and they will continue to operate as necessary, in conjunction with the long-term preventive measures. The Peel Inlet Management Authority appreciates that this is not necessarily the most efficient way to handle the weed problem, and the Public Works Department is investigating ways to improve the weed removal operations.



Reducing the input of phosphorus

The research studies have shown that the input of phosphorus to the estuary can be considerably reduced by modifying fertilizer practices on agricultural land on the coastal plain. (See leaflet No. 5). The recommended practices are:

- soil testing to determine the amount of phosphorus present in the soil;
- reducing the use of phosphate fertilizers to levels needed to maintain economic yields (as shown by soil testing);
- using slow-release phosphorus and sulphur fertilizers instead of superphosphate, especially on sandy soils. The "New Coastal Super" is such a fertilizer, and is now available to farmers.

The fertilizer programme was extended to the entire coastal plain catchment early in 1984. After the 1984 winter river flows it will be possible to say with more confidence what reduction in phosphorus input these measures will achieve. However, on the experience of carefully monitored field trials in 1983, it is expected that the phosphorus input to the estuary can be reduced by 30% to 40%. This is a significant step towards improving the condition of the estuary, but not enough to prevent the algal nuisance, except in years of well below average rainfall and river flow. The input would have to be reduced much more — by about 70% — to achieve the management aims on its own.

Increasing phosphorus losses to the sea

Additional measures are therefore needed to reduce the amount of phosphorus available to algae in the estuary sufficiently. This can be done by improving water exchange between the estuary and the sea, so flushing more phosphorus out to sea.

At present, tidal exchange is too small to flush enough phosphorus out to sea to prevent the excessive growth of algae in the estuary. This is because the ocean tide is small, and the only channel to the sea — the Mandurah Channel — is long and narrow with obstructions at both ends. It is also remote from Harvey Estuary into which a lot of the phosphorus flows and where much of it now stays.

A new channel to the sea

The most effective way to improve flushing would be to construct a new channel from Harvey Estuary direct to the sea.

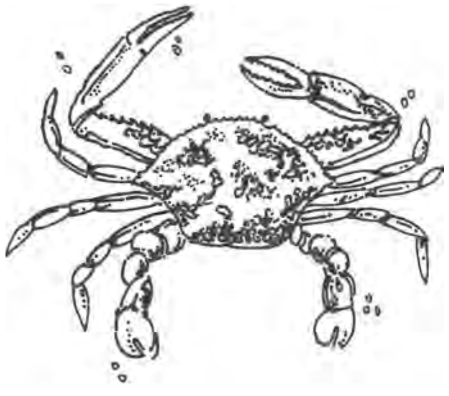
Such a channel would greatly increase the flushing rate for Harvey Estuary, probably at least halving the phosphorus available to algae there, and greatly reducing it in Peel Inlet.

Preliminary calculations indicate that the channel should be about 200 metres wide and could be located in the vicinity of Dawesville. However, more detailed studies are needed to establish a precise location and design, and possible effects on the estuarine environment. The studies will include a geotechnical survey of the potential route to identify rock and soil types, and a mathematical model to determine more precisely the effects of the channel on water exchange with the ocean.

Another area to be studied is sand movement and coastal erosion. Training walls would be needed to prevent shoaling at the ocean entrance, and some form of sand by-passing or routine dredging may be required to keep the channel open for navigation.

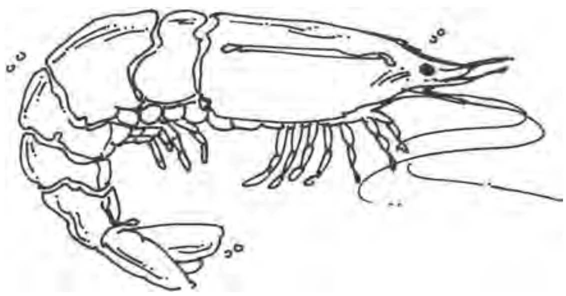
It is clear that the increased flushing would improve the estuarine environment, making it more like the estuary of the Swan or Leschenault Inlet, both of which are healthy estuaries, where the water is generally clear and there is little weed growth. Nevertheless the environment will change and the effects of some of the changes are not easy to predict. For example, a new channel would change the pattern of tides in the estuary, increasing the daily tide from about 5cm to as much as 40cm. How would this affect the many plants and animals living in the shallows and along the shoreline? What difference would it make to people who live near the estuary?

The channel would reduce the salinity range in the estuary, shortening the period when conditions are right for *Nodularia* growth. Also the more marine conditions would probably be a good thing for the fishery because it would encourage marine species of fish, though mullet, which feeds on detritus (decaying organic matter), may not do so well. Juvenile fish should be able to enter the estuary earlier in the season, to feed on the abundant food it provides, and healthier sea grass beds should provide them with more shelter from predators.



It will never be possible to predict with absolute certainty all the changes that a new channel will make to the estuarine environment. However, it is clearly essential to do all that can be done to make sure they are beneficial, and with few or no adverse effects. effects.

If constructed, the channel, in conjunction with the measures to reduce phosphorus input by modifying agricultural practices, would lower the phosphorus level sufficiently to achieve the management aims. Neither measure alone will do so, within an acceptable time, but together they should make the whole estuary healthy and the beautiful place it should be.



The Mandurah Channel

The possibility of enlarging the Mandurah Channel has been suggested from time to time, and the idea has obvious attractions as a means of increasing flushing of nutrients and algae from Peel Inlet. This option has been carefully studied and is discussed in the report, but it is not recommended as part of the preferred strategy.

Widening the channel to 200 metres along its entire length, from the sea to the deeper water of Peel Inlet, would increase flushing and reduce the phosphorus available in Peel Inlet by an estimated 30%. This would reduce the weed problem in Peel Inlet, but would not eliminate it, and it would have little effect on the *Nodularia* problem, particularly in Harvey Estuary. Even in conjunction with the fertilizer program it would not achieve the management objectives and it is for this reason that it is not recommended at this stage.

If, for any reason, it is decided not to proceed with construction of a new channel from Harvey Estuary to the sea, it may be necessary to reconsider this option as a partial solution to the estuary's problems.

Supplementary measures

The report lists several other options which have the potential to contribute to clearing up the algal problems and which may prove to be useful supplementary measures. However, they still require further study before their adoption can be recommended and they will take time to be effective in reducing the input of phosphorus to the estuary. Three of these measures are discussed in leaflet No. 5:

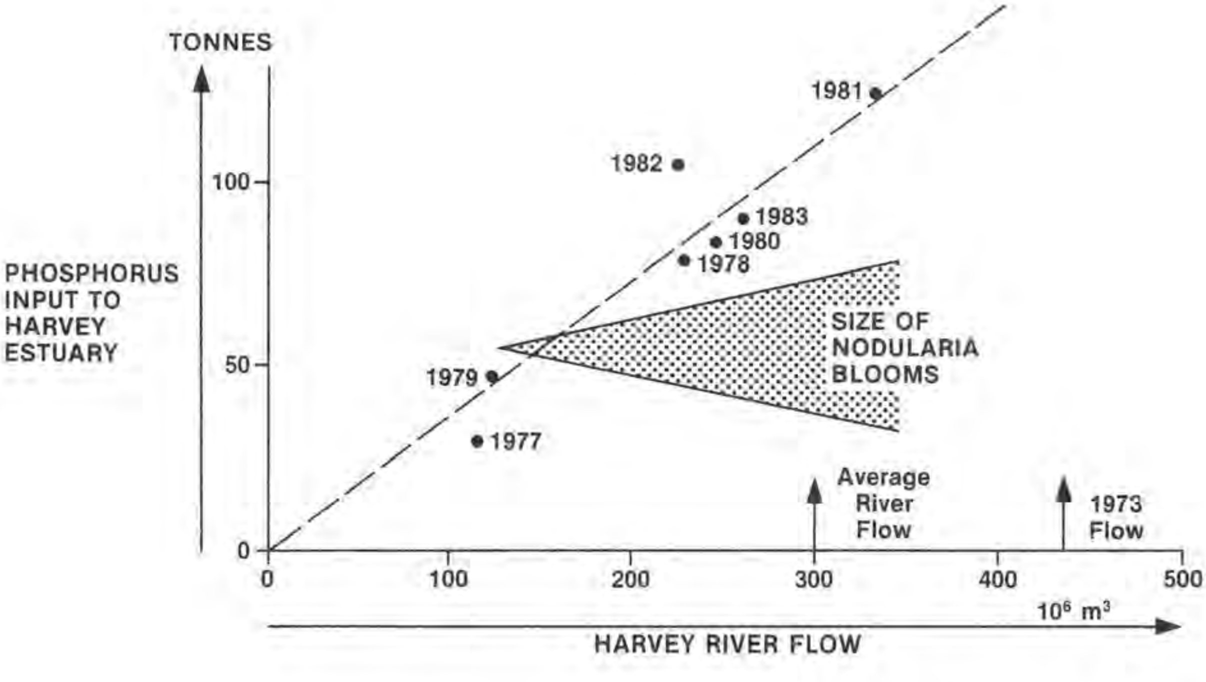
- soil treatment with suitably treated bauxite residue;
- use of wetlands to remove nutrients from rural point sources;
- changes in land use.

Another option is the possible use of algicides to attack the *Nodularia.* The effectiveness of an algicide, and possible side effects of its use, would have to be carefully investigated before a recommendation could be made.

Further clearing and drainage on the coastal plain could negate the beneficial effects of the management strategy and cause continuing deterioration in the condition of the estuary. It should, therefore, be discouraged, at least until other measures have had time to achieve the management objectives.

The final decision

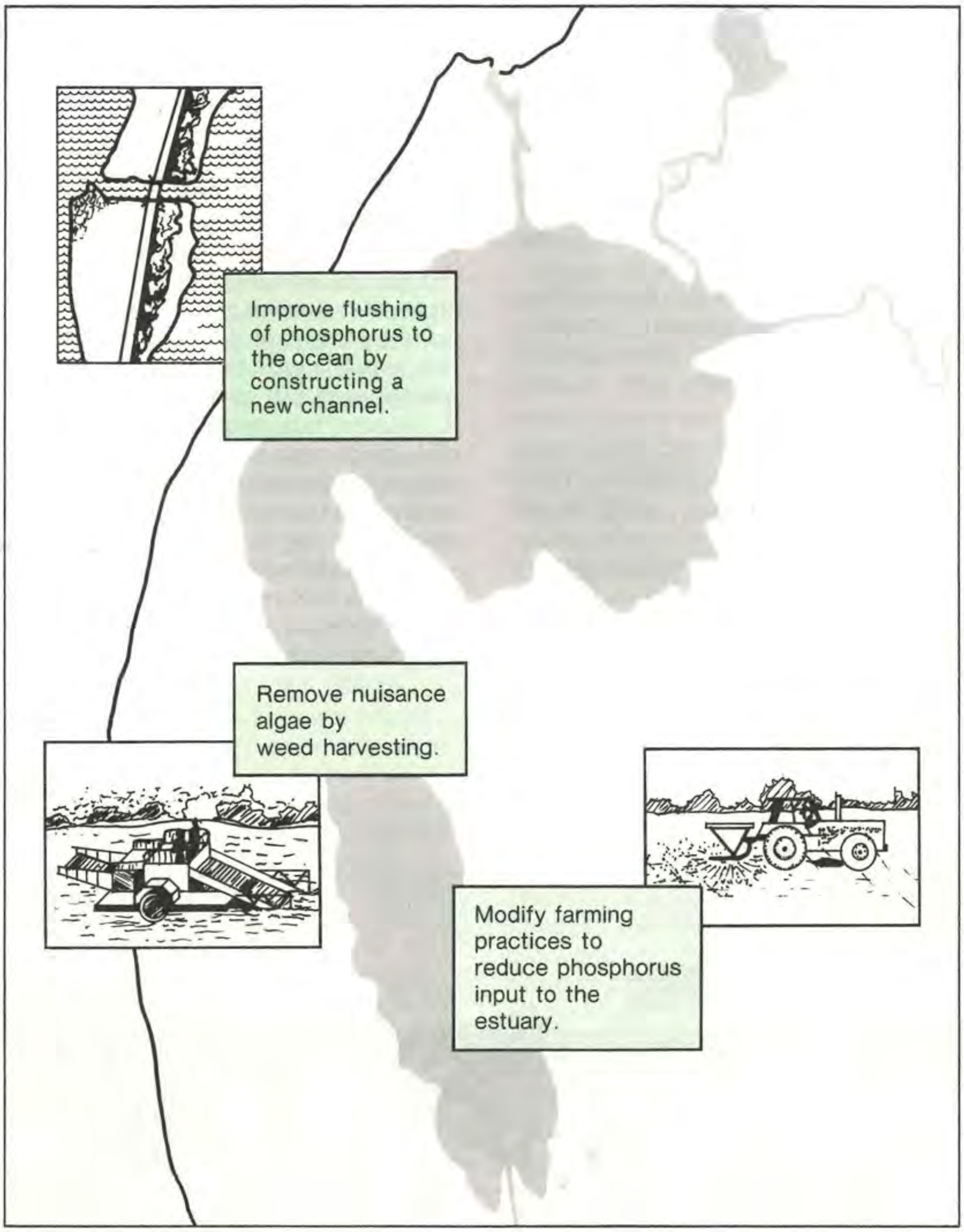
The report brings together the conclusions of investigations which have been undertaken on the estuary's problems and its management. It has been released now to keep people informed on progress of the management procedures which are already underway — the weed harvesting and beach clean-up, and the fertilizer program — and on current thinking with regard to further management measures. These further measures, including a new channel to the sea, are now being subjected to more intensive study, and a final decision as to the best strategy for management cannot be made until these investigations have been completed later this year. Early in 1985 a report on these studies, together with detailed recommendations for management of the estuary, will be presented to Government.



River flow and phosphorus input to Harvey Estuary, and *Nodularia* blooms.

This diagram shows that the size of *Nodularia* blooms depends greatly on the amount of phosphorus that flows into the estuary, and this in turn depends on the amount of river flow from the catchment. There were no blooms in the dry years 1977 and 1979. The big bloom of 1981 (the wettest year of the study) lasted into February 1982 because of the heavy January rains in that year. There was a bloom in 1973, but it was probably not as bad as those of recent years, despite the greater river flow.

The preferred strategy



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Department of
Conservation &
Environment

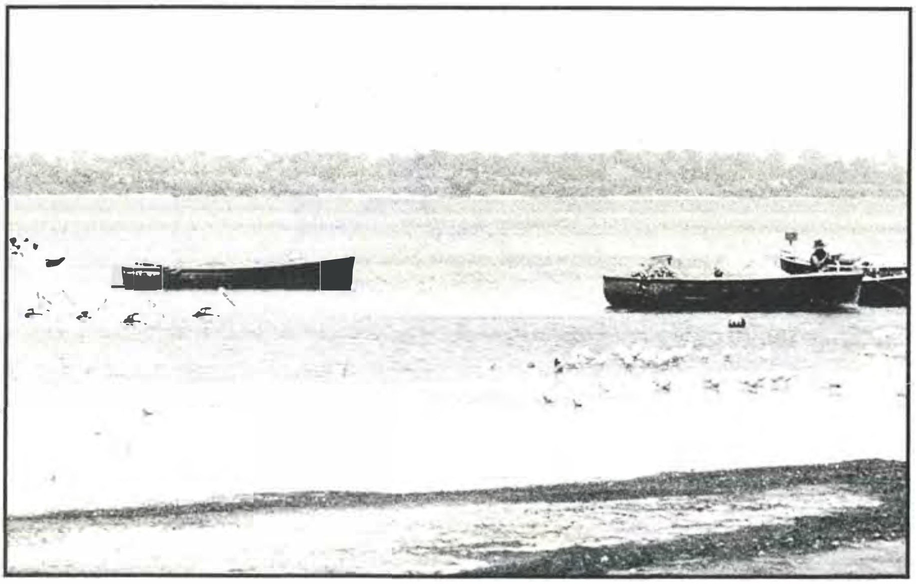
NO 8
OCTOBER
1984

PEEL – HARVEY ESTUARY PROGRESS

BULLETIN NO. 146

THE LIFE IN THE ESTUARY

1. **The plants and animals in the Peel-Harvey Estuary.**



Living in the Estuary

An estuary is a partially enclosed coastal body of water where fresh water from the land mixes with salt water from the sea and as such it is a place of constant change. The rivers pour their water into it or dry to a trickle with the changing seasons and the tides alternately flood the banks and expose them to the air. These constant changes present special problems for the plants and animals living there.

Salinity (saltiness) of the water varies both with the tides and seasonally. In the winter, when the rivers flow, the water in the Peel-Harvey estuary can be almost fresh (about one part per thousand) but by the end of summer it is saltier than sea water (35 ppt), sometimes as high as 50 ppt.

Only a few plants and animals can cope with such wide variations. Most marine animals will die in freshwater, and most freshwater animals (living further upstream) die in salt water. Estuarine plants and animals, however, have ways of dealing with the salinity range.

Some only live in parts of the estuary where conditions suit them. For example in Peel Inlet, the seagrass *Zostera* (a marine plant) occurs only near the Sticks Channel, where conditions are more like the sea. It cannot live in low salinities for long.

Some of the larger and more active animals, like the blue manna crab and many marine fish, spread throughout the estuary in summer, but leave it, or retreat to the saltier conditions near the mouth, when the water becomes too fresh for them in winter.

Other plants and animals have physiological means of coping with the changes in salinity, and can stay in the estuary throughout the year. For example the seagrasses *Ruppia* and *Halophila* can both tolerate the salinity range encountered in the estuary. The small mussel, *Xenostrobus*,survives by closing its shell when the water becomes too fresh, sometimes for a period of weeks.

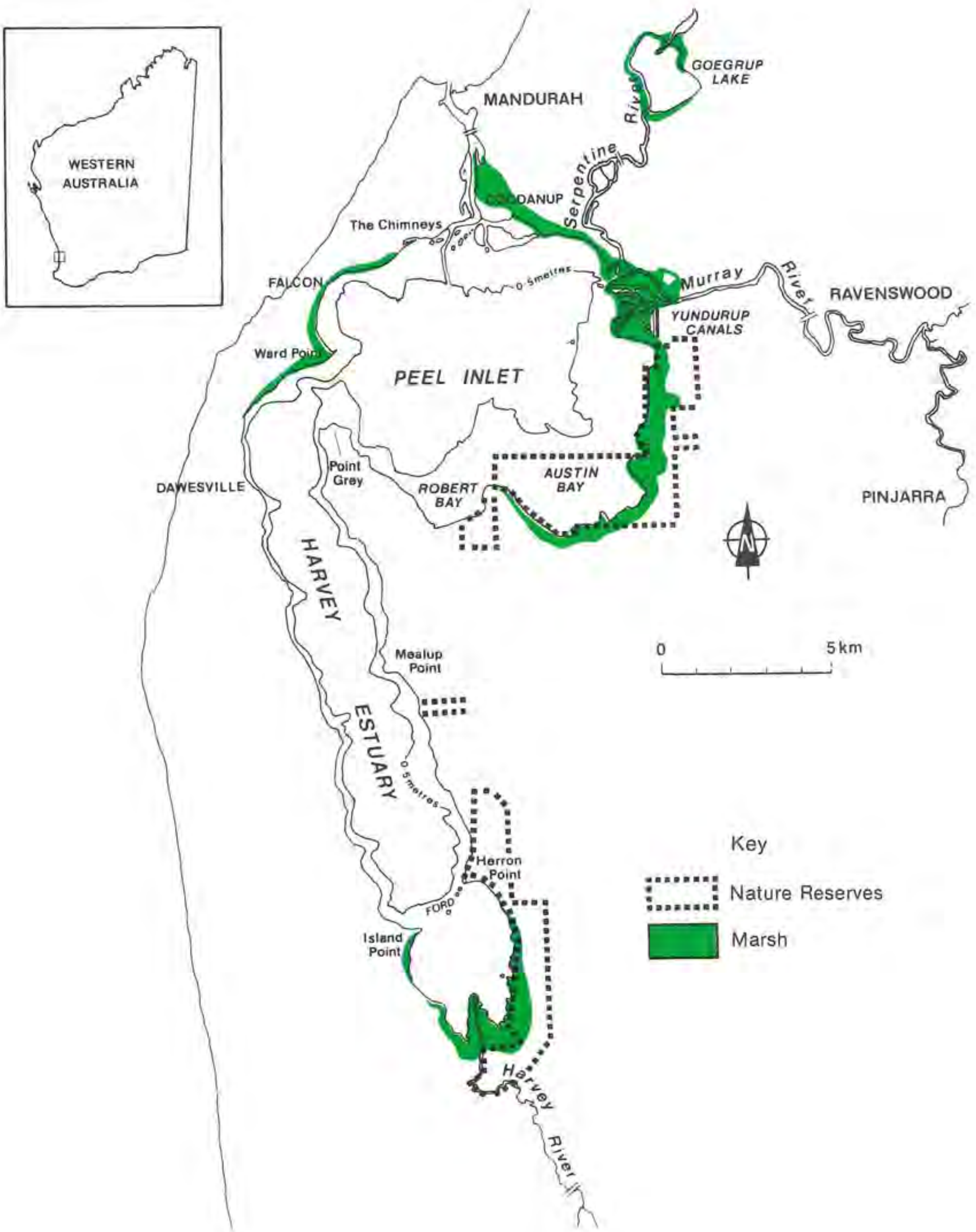
Another problem commonly encountered by plants and animals living in an estuary is the **water movement** caused by tides, winds and river flows. Some plants, like seagrasses, anchor themselves by their roots, while others, like diatoms, are carried in the water and can be flushed to the ocean. Animals can swim against water movements, burrow into the bottom, or attach themselves to plants or to firm supports, like rocks or jetty piles to prevent being carried away.

The Peel-Harvey estuary, with its floor of sand and mud, offers **few hard surfaces for attachment.** There is, therefore, less variety in the animal life than in estuaries like the Swan River where there are more rocky surfaces to support populations of mussels and barnacles. Most seaweeds also require a surface for attachment, and they are uncommon in Peel Inlet, where they also find the salinity range too great. Instead, the large green algae like the sea-lettuce *(Ulva)*, which tolerate the wide range of salinity and do not need to be attached to surfaces, thrive in the sandy basins.

The Algal Problem

Because relatively few species have adapted to live in the widely varying conditions of an estuary, those which can live there face less competition and often reach large quantities. When conditions are right for particular plants or animals to grow and reproduce they can sometimes reach such large numbers that they dominate the life in the estuary.

This is now the case in Peel Inlet, where the large green algae, fertilized by the nutrients brought in by the rivers, flourish in the warm clear water over the summer. They are blown ashore and accumulate, smothering the seagrasses and fringing plants, and decomposing in the shallows and on the beaches with a nauseating smell. Not all the effects are harmful, however. Small invertebrate animals, like shrimps and snails, thrive in the algae, providing food for fish and birds. On the other hand the annual blooms of the blue-green alga *Nodularia* make conditions unfavourable for fish. Then, when the *Nodularia* die and decompose the oxygen in the water is used up and great numbers of small fish, worms and other small animals die too.



Nature reserves on the Peel-Harvey estuary

Much of the water's edge carries a thin fringe of marsh; more extensive areas are shown in green.

The Shoreline

The swamp she-oak and the salt-water paperbark are common along the shoreline, where salt water affects the vegetation. Samphire marshes with their succulent plants occur on low lying land around the estuary where they are spasmodically inundated by water. The most extensive marshes are along the eastern shore of Peel Inlet, around Creery Island and at the southern end of Harvey Estuary.

Rushes *(Juncus)* and sedges grow in many places along the shores of the estuary. They usually form only a narrow fringe along the shoreline, although large meadows occur in shallow water at the southern end of Harvey Estuary, extending from the waterline to the samphire marshes behind.

The wetlands (marshes and rushes) represent only about 10% of the total area of the estuary, but they are important to the life within it. They provide a habitat for many water birds and the small animals on which they feed, and also play a role in storing and releasing nutrients in the estuary (See leaflet 9). The rushes stabilize the shorelines, protecting them from erosion by wave action.

Samphire (Common species are *Sarcocornia blackiana* and *Sarcocornia quinqueflora)*

The sedge, *Bolboschoenus caldwellii* (previously referred to as *Scirpus)*

The rush, *Juncus kraussii*

The swamp she-oak *Casuarina obesa*

The saltwater paperbark *Melaleuca cuticularis*

Ruppia megacarpa

Halophila ovalis

The Shallows

The shallow sandy marginal flats support a thin carpet of seagrasses. Unlike the algae, these are rooted, flowering plants. There are two kinds — *Ruppia* (sometimes called wire weed or gardie weed) grows in the shallower water in Peel Inlet, especially on the Coodanup flats. It has long thin leaves on its wiry stems and flowers on spiral threads. In the slightly deeper water, the paddle-weed, *Halophila*, dominates.

The seagrass leaves and shoots detach in autumn - winter, and are washed ashore. Unlike the algae, however, they decompose slowly and do not cause offensive accumulations on the beach. The seagrasses form only a thin carpet now, but when the water was clearer they grew in great quantities and there are reports that large piles of seagrass were once carted away from the beaches to use as mulch.

Growing on the seagrasses, in the water, and on the bottom of the estuary, are microscopic single celled algae called diatoms. They sometimes form a "fur" on the seagrasses, reducing the light to the leaves and inhibiting their growth.

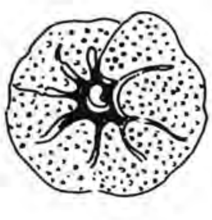
The seagrasses are also sometimes smothered and killed by accumulations of large green algae which drift into the shallows from where they grow in deeper water. This is undesirable because the seagrasses perform an important role in the estuary. Their roots help to hold the sediments together, stabilizing the floor of the estuary, and they provide food for the many black swans and some of the ducks.

The sandy sediments of the shallows, with their cover of seagrasses and algae, provide habitats for a variety of small invertebrate animals which are the main part of the diet of many of the fish and birds.

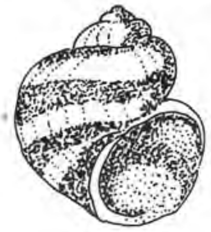
The sediments contain large numbers of microscopic, single celled animals called *Foraminifera*, which secrete chalky, many chambered shells. There are many types, each with a distinctive shell, and more than fifty species have been identified in the Inlet Channel. Further into the estuary, where the water is fresh in winter, only one species *(Ammonia)* is common.

Epiphytic diatoms
(microscopic)

Ammonia beccarii (x 200, approximately)
(photograph courtesy of M. Apthorpe)



Ammonia beccarii
(microscopic)



3-4mm

Hydrococcus brazieri
(previously *graniformis)*

Another group of animals found in large numbers on, and buried in, the sandy bottom is the molluscs. Over thirty species have been identified in the estuary, but only a few are common. One of the most common is the small (3 to 4 mm) snail, *Hydrococcus*, which is abundant in Peel Inlet (up to 20,000 per square metre). The small (2 to 3 mm) bivalve, *Arthritica*, also occurs in large numbers in sandy areas throughout the estuary. Like *Hydrococcus* it is an important part of the food of some of the bottom-feeding fish like whiting, bream and yellow-eye mullet, and many wading birds.

Two kinds of mussel attach to piles and other wooden structures — the edible mussel, *Mytilus*, and the small *Xenostrobus*. *Mytilus* seldom survives the fresh water of winter.

Another bivalve, *Anticorbula*, which superficially resembles a mussel, is common on logs in the tidal rivers, and small ones are sometimes abundant in the sandy marginal shallows.

Buried quite deep in the sediments in Peel Inlet, the bivalves *Tellina* and *Sanguinolaria* feed by putting up a tube or siphon. The siphons, waving around on the surface, look like small worms. They are often eaten by wading birds, and the molluscs then grow new ones. Another bivalve, *Spisula*, is sometimes very common, especially in deeper water.

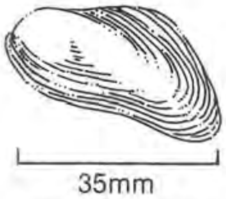
2-3mm

Arthritica semen

Arthritica shells, Harvey estuary

80mm

Mytilus edulis



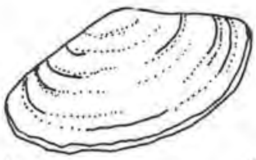
35mm

Xenostrobus securis

Other shells found in the estuary are a reminder of the greater diversity of animals which lived there about 4,000 years ago, when conditions were more marine. Cockle shells, *(Katelysia)* are abundant, although cockles died out in the estuary over 3,000 years ago. They are still common in some south coast estuaries where conditions are more marine.

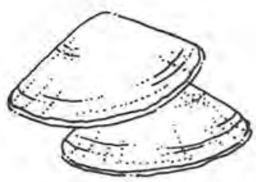
15mm

Anticorbula amara



60mm

Sanguinolaria biradiata

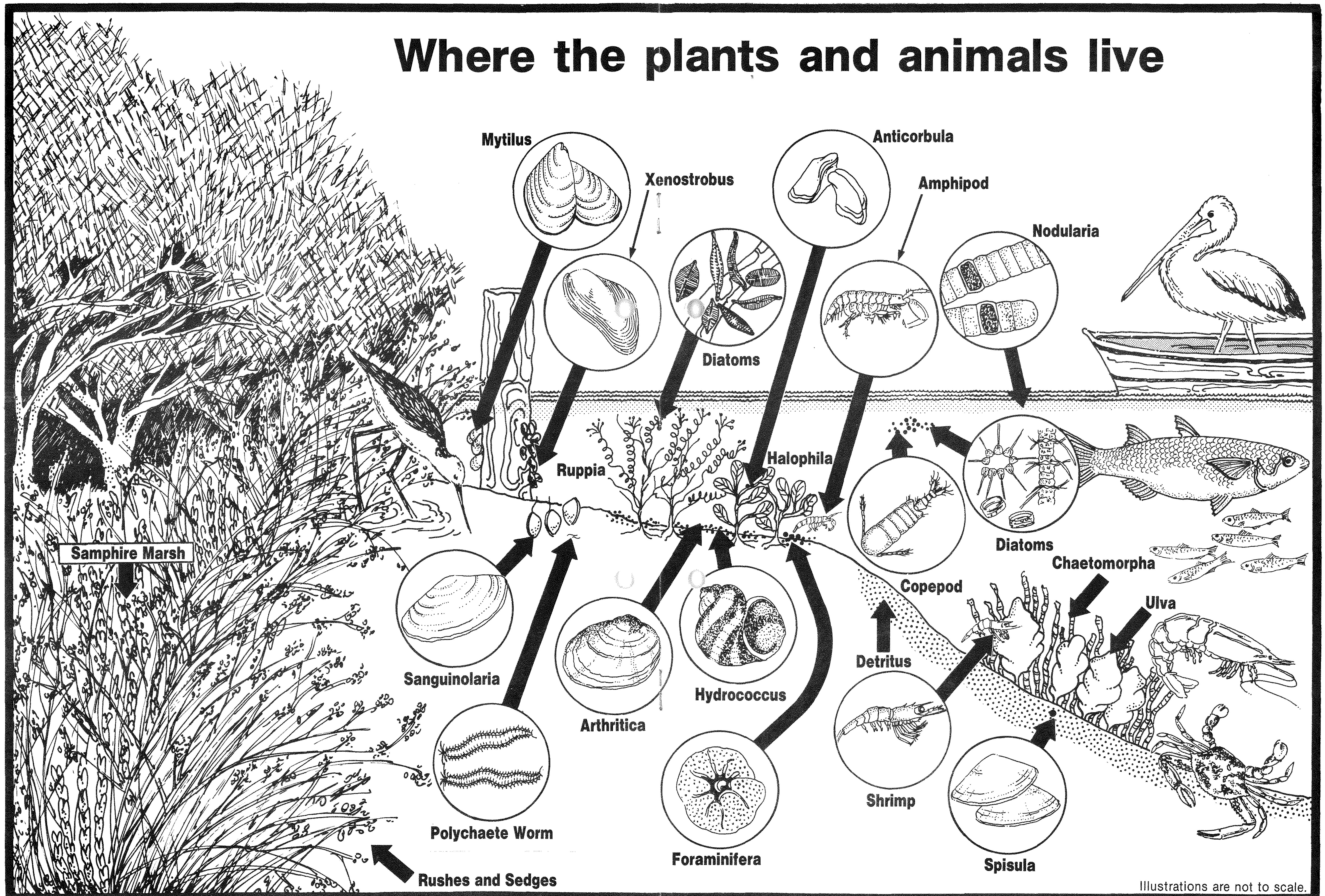


20mm

Spisula trigonella

(Scales indicated are approximate sizes of adults)

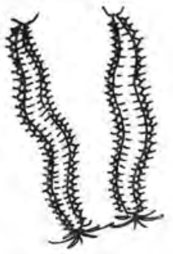
Where the plants and animals live



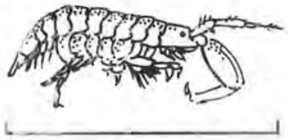
Illustrations are not to scale.

Also in burrows in the sediments, and among the masses of algae in the shallows, are polychaete worms (polychaete means many bristles). Six species are common in the estuary. The most abundant are *Ceratonereis, Haploscoloplos, Prionospio* and *Capitella*. They are an important part of the diet of some fish and wading birds.

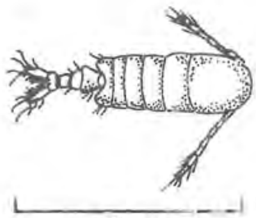
Small crustaceans - amphipods, copepods, shrimps and mysids - are found among the seagrasses and algae. The amphipods *Paracorophium* and *Corophium* live in tubes on the sandy bottom and on the algae. Another amphipod, *Melita*, can also be enormously abundant, and on summer nights large numbers enter the water and become part of the plankton. Copepods, and the shrimp-like mysids, also live on the bottom during the day and are planktonic at night. This behaviour probably helps to protect them from fish which feed during the day, but they are nevertheless eaten by fish such as cobbler and yellow-eye mullet. The shrimp *Palaeomonetes* is common among the algae and seagrasses, feeding on small plants and animals.
It is an important food for predatory fish like western sand whiting, tailor and mulloway (see leaflet 9).



Polychaete worm

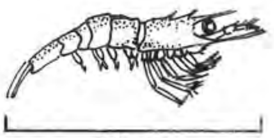


15mm
Corophium



1-2mm
Gladioferens imparipes

The shrimp, *Palaeomonetes australis*



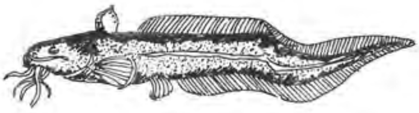
40mm
Palaeomonetes australis

The molluscs, polychaete worms and small crustaceans provide an abundant food supply, which, together with the protective cover offered by the seagrasses and algae, make the shallow banks the most important fish "nursery" areas in the estuary.

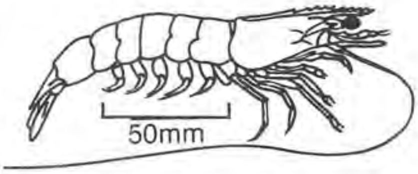
A few fish, like cobbler and bream, spend their whole life in the estuary, while others, including sea mullet, yellow-eye mullet and tailor, breed in the sea and use the estuary mainly as a nursery habitat for the juvenile fish, or as a feeding area. Blue manna crabs and western king prawns also enter the estuary to feed and grow.

The fish, crabs and prawns are the basis of the largest estuarine professional, and one of the largest amateur, fisheries in Western Australia (see leaflet No. 3: The Algae and the Fishery).

Blue manna crab
Portunus pelagicus



Cobbler
Cnidoglanis macrocephalus



Western King prawn
Panaeus latisulcatus

Black swan,
Cygnus atratus

The Peel-Harvey estuary is probably the most important estuary in south western Australia for waterbird conservation. At least 70 species use the estuary and the lakes and swamps along its eastern margin. Although relatively few breed in the estuary, it is an important feeding area, and a drought refuge when wetlands further inland dry up over the summer.

The most important habitats for waterfowl, including Black Swans, Grey Teal, Black Duck and Australian Shelduck, are the shallows off the eastern and southern shores of Peel Inlet, and the southern Harvey Estuary. These shallows and the shallows of the northern shore of the estuary are also rich feeding grounds for wading birds, such as the Banded Stilt, which may occur in flocks of ten thousand or more. Many of the birds which use the estuary, like the Red Necked Stint, Curlew Sandpiper, Knot and Godwit are summer migrants with breeding grounds in the Northern Hemisphere. A separate leaflet in this series will be devoted to the birdlife of the estuary.

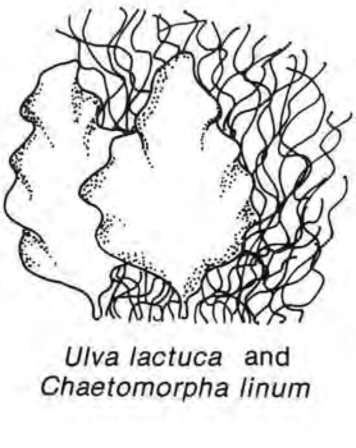
Banded stilt, *Cladorhynchus leucocephalus*
(photograph courtesy of A.G. Wells).

The Basins

The deeper water (1 to 2 metres) of the **Peel Inlet** basin is the main growth area for the beds of large green algae. Since the mid 1960's these algae have thrived to such an extent that large masses have drifted ashore and accumulated on the beaches, causing a major nuisance.

The types of algae have changed over the years. Until 1979 the dominant species was goat weed *(Cladophora)*. Rope weed *(Chaetomorpha)*, which was uncommon in 1978, increased dramatically over the summer of 1978-79 and has been abundant ever since. In 1983 the sea-lettuce *(Ulva)* became a major nuisance. The reason for this succession is not clear, but it probably reflects changing conditions in the estuary.

The algal beds support large populations of small animals, like amphipods and shrimps. They also shelter the fish and crabs from predatory birds, such as pelicans and cormorants. Some of the benthic invertebrates, including the bivalve, *Spisula* and the polychaete bloodworm prefer the muddy bottom of the deeper basins, but most occur in greater numbers in the sandy shallows.



Ulva lactuca and
Chaetomorpha linum

Underneath the living beds of algae a black ooze, consisting largely of decomposing algae, accumulates. The rotting algae, together with other plants, dead animals and animal faeces in various stages of decomposition, make up the detritus which is the basic food store in the estuary. (See leaflet 9.)

Study team members sample the rotting algae.

Planktonic diatoms (microscopic)

Nodularia spumigena (microscopic)

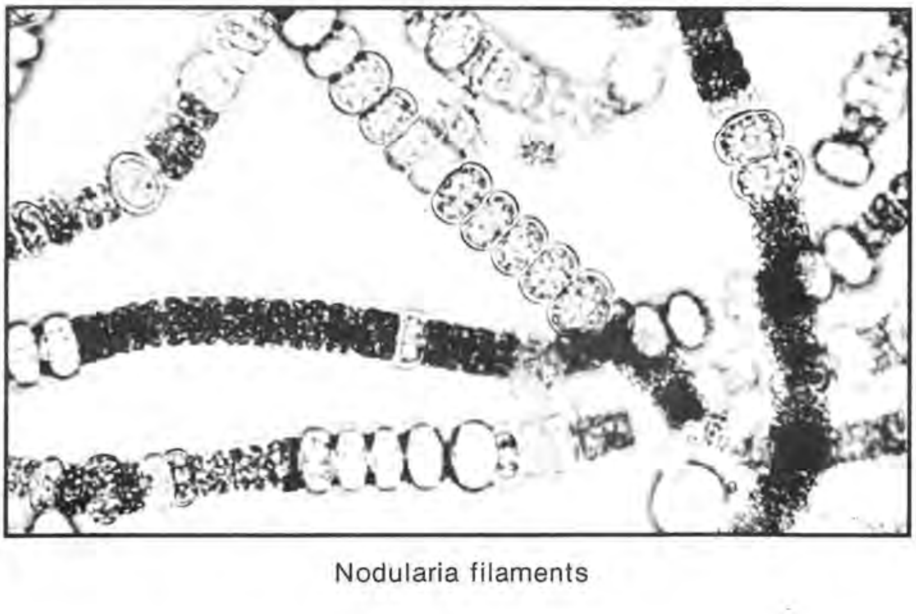
The large green algae do not grow so well in **Harvey Estuary**where the water is turbid (cloudy) due to more suspended sediment and more phytoplankton (microscopic plants such as diatoms and blue-green algae).

Diatom blooms occur every winter, when the river flow brings in its load of phosphorus. They turn the water murky brown. Tiny animals in the water, zooplankton, are dominated by the copepod, *Gladioferens*, which spends the days on the bottom of the estuary, entering the water at night to feed on the diatoms. In spring, as the nutrient supply drops, and the feeding copepods take their toll, the diatom bloom collapses. The diatoms decompose, and the nutrients again become available to feed plant growth. The diatom bloom has been followed in recent years by a bloom of the blue-green alga *Nodularia*. The microscopic filaments of *Nodularia* turn the water green and on calm days float to the surface to form a green scum.

Since 1982 another blue-green alga, *Oscillatoria*, has appeared, principally in Harvey Estuary. It forms a black slime over the bottom, and mats of this break off and float to the surface.

Like the large green algae, the blue-greens are blown ashore where they rot with a nauseating smell.

The *Nodularia* bloom ends in the summer, as nutrient supplies run low and salinity increases. It may be followed by another diatom bloom, or its nutrients may contribute to the growth of the large green algae.



Nodularia filaments

The Food Web

The fish, crabs and prawns in the Peel-Harvey estuary support a profitable fishery, as well as attracting many visitors to the Mandurah area. Many people are also attracted by the rich bird life, and the scenic beauty along the shores.

The smaller members of the plant and animal life, like the plankton and the tiny animals hidden in the sediments or amongst the weeds, often go almost unnoticed. However, it is these small creatures, and the rotting organic detritus and bacteria on the estuary floor, which provide the food supply for the larger animals — the fish and the birds. The next leaflet in this series will deal with the food web — how the plants and animals in the estuary depend on each other.

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Note: Bulletin No. 160 includes a comprehensive list of publications on the Peel-Harvey estuary.

Department of
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PEEL – HARVEY ESTUARY PROGRESS

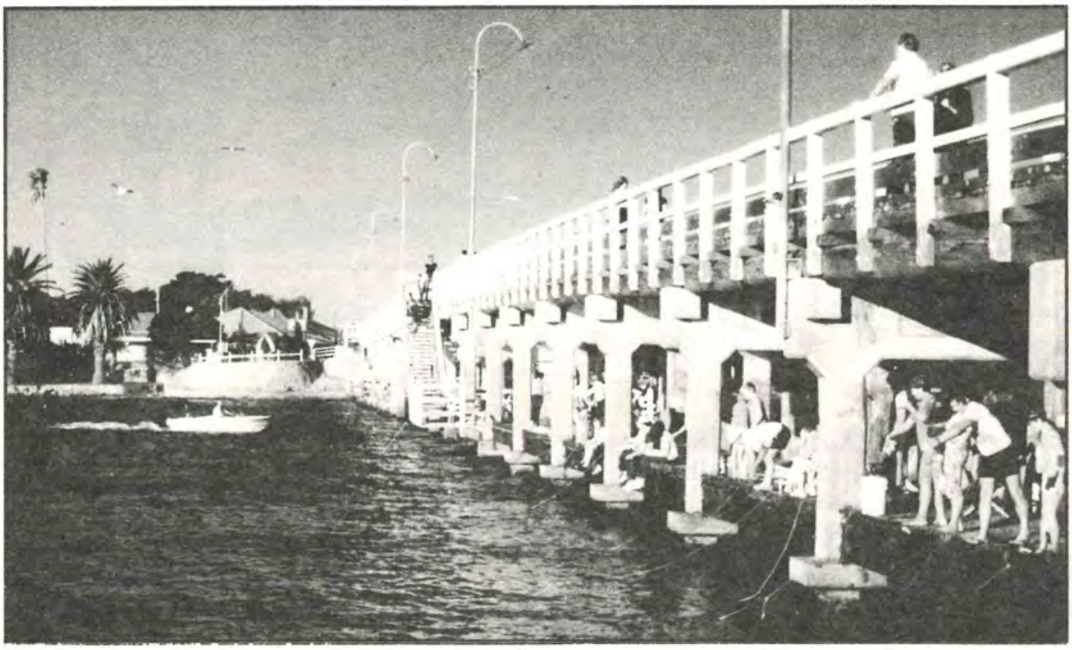
BULLETIN NO 146

NO 9

NOVEMBER 1984

THE LIFE IN THE ESTUARY:

2. The Food Web



Fishing from the Mandurah Bridge. (Photograph courtesy of the Mandurah Tourist Bureau.)

Man has long recognised the value of estuaries for food production, especially for fish, crabs and prawns, and for the rich bird life they support.

The Peel-Harvey estuary supports the largest professional estuarine fishery in Western Australia, providing a catch worth over $1 million each year, as well as a popular amateur fishery. Fishing, crabbing and prawning in the estuary's shallow waters are attractions which bring many holidaymakers to Mandurah.

Others come to see the abundant birdlife — the Peel-Harvey is the most important estuarine bird habitat in southern Western Australia. At least 70 species of birds have been recorded there, including large populations of pelicans, swans, ducks and wading birds. Several are summer migrants which have their breeding grounds in the northern hemisphere.

The fish, crabs and prawns and bird life are the most visible and economically important part of the complex, interwoven pattern of life in the estuary, but they are only a part. Microscopic plants and animals in the water and on the estuary floor provide food for animals like worms, shrimps and molluscs, which in turn are food for fish, crabs and wading birds. Predatory birds, like pelicans and cormorants, feed on the fish, while swans and ducks graze on seagrasses in the shallows.

Any change in the balance of life in the estuary, for example the great increase in the growth of green algae in Peel Inlet, affects the other plants and animals. The algal beds have provided a habitat for shrimps and other small animals, as well as protective cover for young fish, and have probably contributed to the increased numbers of fish in the estuary. The algae themselves are not an important food source, but the numerous small animals which live among the algae are food for many fish and wading birds. Such changes alter the whole balance of life through the complex food web.

The Food web

All animals and plants in the estuary are linked through the food web. Plants use the energy of sunlight to convert nutrients in the water and the sediments (especially nitrogen and phosphorus), and carbon (from carbon dioxide from the air), into plant tissue. Flowering plants, including seagrasses and marsh plants, take up nutrients through their roots, while the algae take theirs directly from the water. The plants may be eaten, or when they die and decompose their nutrients are released and can be used again. Small animals provide food for some of the large animals, and these in turn may be eaten by larger animals. This is the food web.

At its simplest, it may be thought of as a simple chain:

Tertiary Consumers ↑	Carnivores (eg pelican, man)
Secondary consumers ↑	Carnivores (eg fish)
Primary consumers ↑	Herbivores (eg snails)
Primary producers ↑	Plants (eg diatoms)
Energy & Nutrients	

It is really much more complicated than this and even the food web shown in this leaflet is a very much simplified representation of what happens in the estuary.

The Marshes

There are marshes on either side of the Mandurah Channel, along the eastern shore of Peel Inlet and at the southern end of the Harvey Estuary. Small meadows and clumps of rushes and sedges also occur around much of the shoreline (see Leaflet 8, The Life in the Estuary: I The Plants and Animals in the Peel-Harvey Estuary).

Although the marshes make up only about ten per cent of the total area of the estuary, they serve an important function in providing feeding areas for birds, and by stabilising the shoreline. The rushes especially play a valuable role by protecting the shores from erosion by waves and the wash of boats.

The marshes also act as a store of nutrients. It has been estimated that the samphire plants in the marshes could convert 90 tonnes of nitrogen and 13 tonnes of phosphorus into new growth each year. When they die and decay most of the nutrients are probably recycled within the marsh, providing a store for the growing plants. Some plant material may be washed into open water and decay there, and algae are washed ashore and decompose in the marshes. However, the marshes probably play only a minor role in nutrient cycling in the estuary as a whole.

The marsh plants themselves are not important food plants, but the marshes provide a habitat for insects, molluscs and other small invertebrates which are eaten by ducks and wading birds.

Seagrasses

Rooted aquatic plants called seagrasses grow in the shallows around the estuary (see Leaflet 8). They grow mainly in spring and summer, taking up nutrients from the sediments through their roots. The leaves and shoots die off and detach in the autumn, decomposing and contributing to the nutrient store in the detritus on the estuary floor. In spring there is new growth from the underground stems with their store of nutrients.

The seagrasses are eaten by the many Black Swans and some of the ducks which use the estuary. The swans graze in water as deep as one metre, where their necks can reach the seagrasses on the bottom.

Black Swans graze on vegetation on the banks and seagrasses in the shallows. (Photograph courtesy of the Western Australian Tourism Commission.)

Diatoms

Growing as a "fur" on the seagrasses are epiphytic (living on the surface of another plant) single-celled algae called diatoms. Other benthic (bottom-living) diatoms live on the estuary floor. These provide part of the diet of the molluscs and of small crustaceans like shrimps and amphipods.

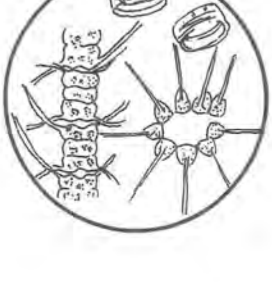
Other species of diatoms are an important part of the plant plankton which drift in the water in the estuary, providing an abundant food supply for the tiny animals — zooplankton — in the water, and for filter feeders such as mussels.

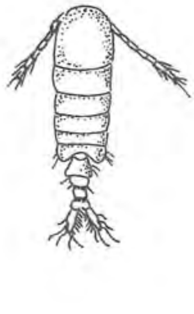
In contrast to the seagrasses, diatoms take up nutrients directly from the water. They multiply rapidly, and under good conditions, with plenty of nutrients, can double their numbers in a day.

When the winter river flow carries its load of nutrients into the estuary, the diatoms quickly take up the phosphorus. The water flowing from the Harvey River into the southern end of Harvey Estuary has high levels of dissolved phosphorus, but by the time it reaches the northern end, phosphorus levels are low and diatoms abundant. The diatom bloom turns the water a murky brown.

Tiny planktonic animals, copepods, take advantage of this rich food supply, feeding on the diatoms and reaching large numbers. In their turn they provide food for small fish.

In spring, as nutrients in the water decrease and the feeding copepods take their toll, the diatom bloom collapses. The diatoms and copepods die and decay and their nutrients again become available to fertilise plant growth.

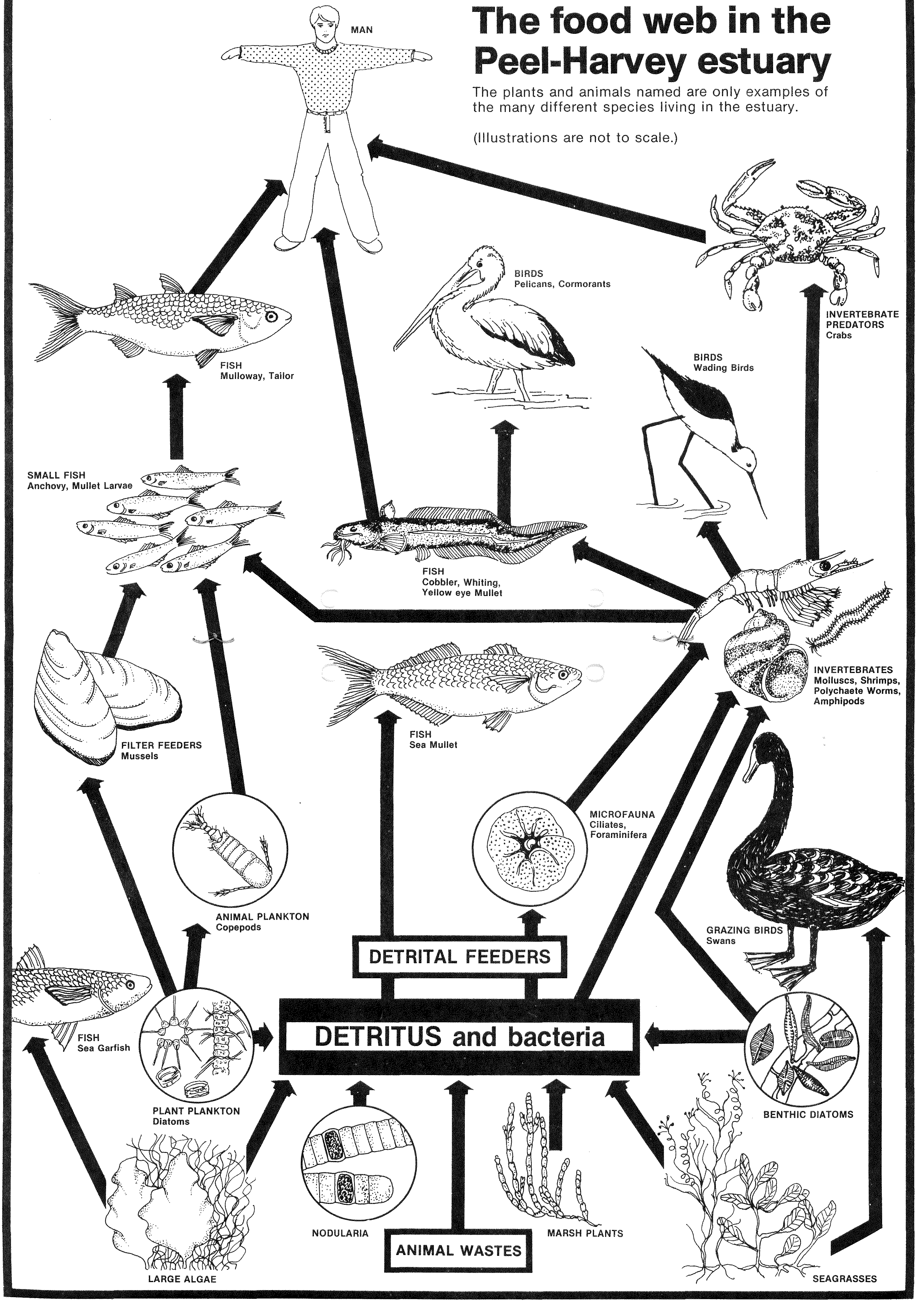




The food web in the Peel-Harvey estuary

The plants and animals named are only examples of the many different species living in the estuary.

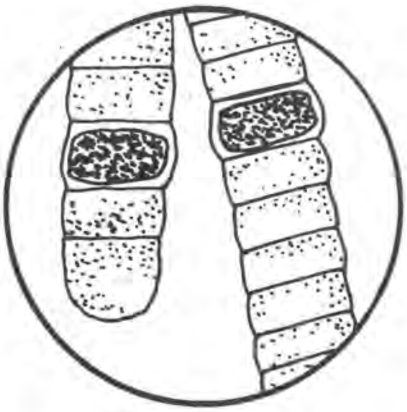
(Illustrations are not to scale.)



Nodularia

As the water warms up, this rich supply of nutrients feeds another kind of plant plankton — the blue-green alga *Nodularia*. This grows as chains of microscopic cells which float in the water. They are lighter than water and on calm days they float on the surface, covering the water like a green carpet. *Nodularia* too can multiply rapidly when conditions are right, doubling its numbers every three days.

Unlike diatoms, *Nodularia* is not eaten by animals in the estuary. In summer, when salinity increases, it dies and decomposes; again the nutrients are released to fertilise another crop of diatoms, or the large green algae which flourish in the warm clear water of Peel Inlet in summer.



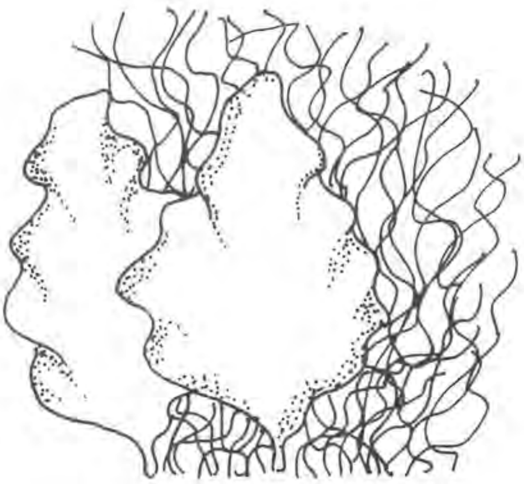
Large green algae

The algae grow in the deeper water (1 to 2 metres) of the Peel Inlet basin. A succession of different species has dominated; for many years it was goat weed *(Cladophora)*, but in recent summers rope weed *(Chaetomorpha)* and sea lettuce *(Ulva)* have been more abundant (see Leaflet 8).

They grow little over the winter, but can take up "luxury" amounts of nutrients from the water, building up a store to be used for growth when conditions are right in the summer. These stores, as well as rich supplies of nutrients from the sediments and decaying diatoms and *Nodularia*, fertilise abundant algal growth.

Increasing nutrient levels in the estuary have caused the large green algae to flourish to such an extent that they have become a major nuisance. They float to the surface and are washed into the shallows and onto the beaches around Peel Inlet, where they decompose with the smell of rotten eggs (hydrogen sulphide).

There is little grazing on the algae, although they are eaten by some fish, principally sea garfish, six-lined trumpeter and yellow-eye mullet. They do, however, provide a habitat for small invertebrate animals like molluscs and shrimps, as well as fish and crabs, and they make a big contribution to the detritus. Underneath the growing algal beds the layer of "black ooze" consists largely of decomposing algae.



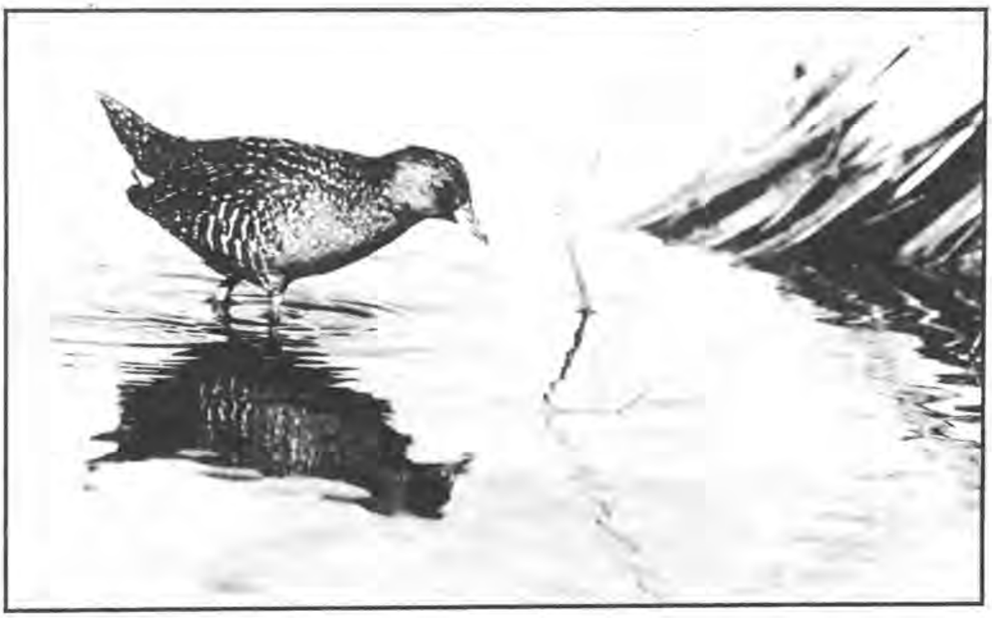
Detritus

Detritus is the organic debris from decomposing plants and animals — a mass of plant fragments, microscopic plants, animal faeces and remains of dead animals. All in various stages of decomposition, it is being broken down by the innumerable bacteria, so making the nutrients available again for plants.

Accumulating on the floor of the estuary, detritus forms a year round store of food and plant nutrients, although it is richer in spring and summer when higher temperatures increase biological production in the estuary.

The dead plant material in the detritus is indigestible to most animals, but the bacteria are food for many animals, from microscopic single-celled animals such as foraminifera to sea mullet. An abundant community of animals feeds on the bacteria-rich detritus and on the diatoms on the estuary floor.

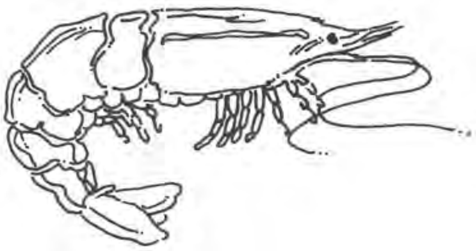
The bivalve molluscs *Tellina* and *Sanguinolaria* bury themselves deep in the sediments. They feed by putting up a tube or siphon which sweeps the surface, sucking in organic particles like a vacuum cleaner. The polychaete bloodworm takes in mud and detritus, and rejects the undigested material as casts. Prawns feed on detritus and on small invertebrate animals which live among the algae. The adult



Australian Crake feed on molluscs, insects and aquatic plants. (Photograph courtesy of A.G. Wells.)

sea mullet are also detrital feeders, sieving it through fine hairs on their gills to extract the bacteria.

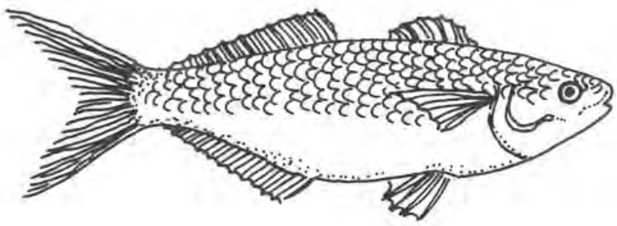
Much of the detritus is very fine and light and easily stirred up into the water by waves, making the water murky. Mussels and other filter-feeders draw in the water and filter out the bacteria and plant plankton on which they feed.



The Carnivores

The small invertebrate animals which feed on the detritus are themselves a rich food source for the fish and crabs which are the basis of the estuary's professional and amateur fishery. Some small fish feed on animal plankton, such as copepods. Others eat the molluscs, polychaete worms, shrimps and other crustaceans which are often present in large numbers in the beds of algae and in the shallows. Yellow-eye mullet, for example, eat a varied diet including plants, molluscs, shrimps, polychaetes, midge larvae and foraminifera. Cobbler feed largely on bivalve molluscs, worms, and small crustaceans like amphipods, while western sand whiting eat polychaete worms and the larger crustaceans such as shrimps.

The larger carnivorous fish, like tailor and mulloway, eat active, moving prey including shrimps and small fish like the southern anchovy.

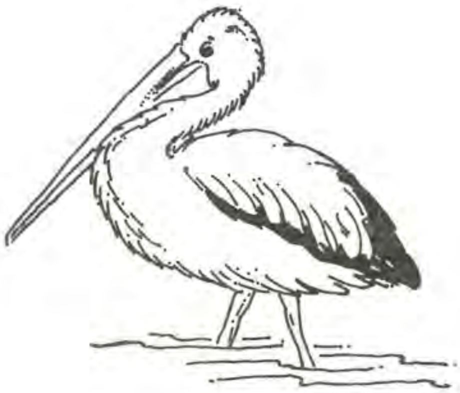


Wading birds, such as the Greenshank, feed on small invertebrates in the shallows, and in the samphire marshes. Many of the waders are migrants which breed in the northern hemisphere. They make the long journey to their feeding grounds in our estuaries to escape the northern winter.

Eastern Curlew can be seen feeding on small crabs in the entrance channel. Yellow-billed Spoonbills gather their food from the shallows by seiving the mud with their beaks. Ducks including the colourful Australian Shelduck, feed on molluscs and insect larvae in the samphire marshes and among the decaying algae.

Great Egrets visit the estuary to feed on fish and large invertebrates, like prawns, and White-bellied Sea-Eagles can sometimes be seen fishing. Large numbers of cormorants and pelicans also feed on fish in the estuary. The pelicans perform a particular service by eating the cobbler heads, with their poisonous spines, which are discarded by fishermen. (The bird life in the estuary will be dealt with in more detail in a future leaflet in this series.)

At the top of the food chain, man uses the estuary as a fishery resource (see leaflet 3).



Eutrophication and the food web

Clearing and fertilising farmland in the catchment over the last 30 to 40 years has increased the amount of plant nutrients, especially nitrogen and phosphorus, running into the estuary. Much of the phosphorus carried into the estuary each year in the winter river flow is trapped by the sediments or taken up by the plants and used for plant growth (annual blooms of diatoms in winter, blue-green algae in spring-summer and large green algae in summer-autumn), rather than being carried out to sea.

The diatoms provide an increased food source at the bottom of the food web and the algal beds provide a habitat for the small invertebrates, and shelter for fish, and have probably contributed to increased numbers of fish in the estuary. However, only a small part of the plant growth in the estuary is eaten by plant-eating animals and the increased plant production has outstripped any increase in consumers which eat them. Most of the nutrients trapped by the plants are recycled in the estuary through decay, and are used again by plants or added to the sediment.

References

Department of Conservation and Environment, Report No. 9. The Peel-Harvey Estuarine System Study, 1980.

Bulletin No. 146. Peel-Harvey Estuary Progress (Series of leaflets).

Bulletin No. 149. Fish and Benthic Faunal Surveys of the Leschenault and Peel-Harvey Estuarine Systems of South-Western Australia. 1984.

Instructions to readers:

- Further pamphlets will be issued from time to time. Each will be distinguished by a characteristic number eg Bulletin 146 No.7.
- When requesting a pamphlet from the Department please specify the Bulletin and pamphlet numbers.
- Pamphlets are available free of charge to organizations and individuals concerned with the estuary.
- For further information contact the Department of Conservation and Environment, 1 Mount Street, Perth, or phone (09) 322 2477.

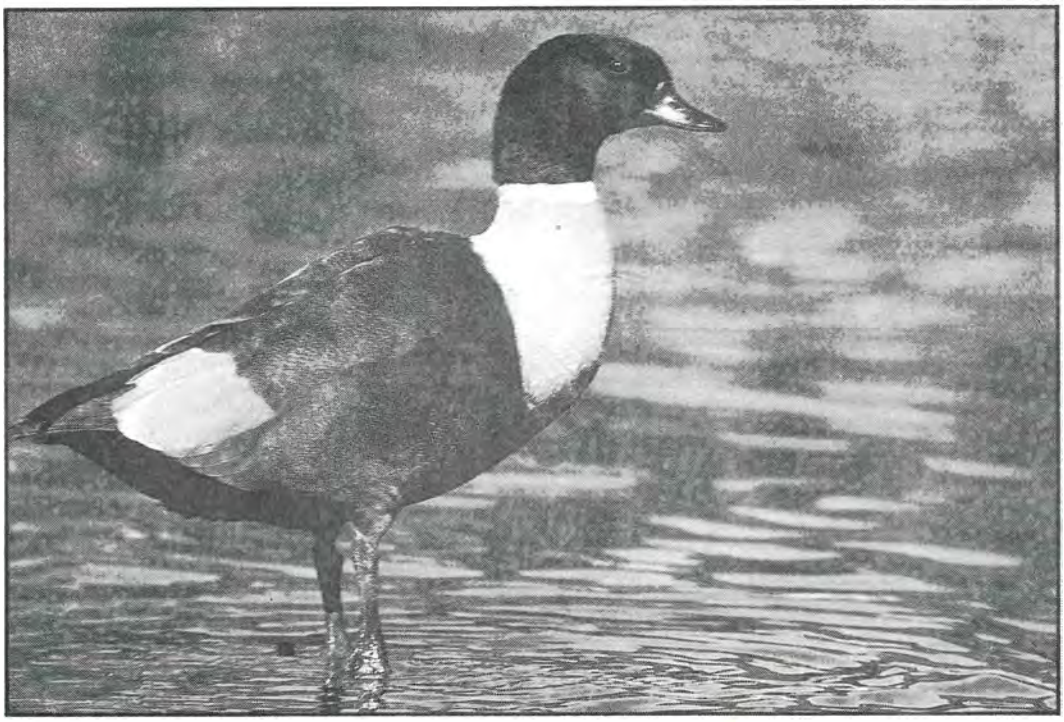
Department of
Conservation &
Environment

PEEL — HARVEY ESTUARY PROGRESS

NO 10
MARCH
1985

BULLETIN NO 146

THE BIRDLIFE OF THE PEEL - HARVEY ESTUARY



Australian Shelduck (Mountain Duck) (Photograph courtesy of the Department of Fisheries and Wildlife)

The variety of birdlife

The Peel - Harvey estuary is one of the most important waterbird habitats in south-western Australia. Over eighty species of birds live in or visit the estuary to take advantage of the permanent water and rich food supplies, and the variety of habitats it offers for loafing, feeding and nesting. Some of the birds are very familiar, especially the pelicans and cormorants which fish in the estuary, the Black Swans and colourful Australian Shelducks (Mountain Ducks), and the ever-present Silver Gulls. In summer as many as 20,000 waders may visit the estuary, some flying from as far away as Siberia. Red-necked Stints and Banded Stilts are often seen in flocks of thousands feeding in the sandy shallows.

Other birds, like the Australian Crake, are seldom seen because they are easily disturbed by people, or prefer dense plant cover. Some, for example Pectoral Sandpipers, only visit the estuary occasionally, or in small numbers, and are usually spotted only by experienced birdwatchers.

How the birds use the estuary

Only a few birds **breed** in the estuary.

The Australian Pelican sometimes nests on Boodalan Island and the islands in Nirimba Cay. Boodalan and Nirimba are aboriginal names for pelican. Two eggs are laid in a nest of sticks and plants, but success is limited by water levels and human disturbance. Silver Gulls also nest on the islands.

Black Swans sometimes build their nest mounds of sticks, leaves and rushes in the samphire marshes, especially in the nature

reserve on the eastern shore of Peel Inlet and in nearby swamps. They lay 3 to 9 eggs in early winter and, like the pelicans, both parents share the task of incubating the eggs.
A few Australian Shelducks, Pacific Black Ducks and Grey Teal also breed in the marshes, but the estuary is not an important breeding area for ducks. Like the swans, most breed in swamps further inland.
Red-capped Plovers nest in small depressions in sand or plant debris on beaches around the inlet. The nests are sparsely lined with shells, stones or dried leaves.
Although only a few birds breed in the estuary, it is nevertheless an important area for the many kinds of birds which breed in other places and rely on the estuary as a regular feeding site, or as a drought refuge when lakes and swamps dry up over the summer.
Some, like Darters, Little Black Cormorants and Little Pied Cormorants, nest in swamps nearby and visit the estuary every day to **feed**. Others come from further afield, from their nesting sites on offshore islands or swamps further inland, to take advantage of the estuary's rich food supplies. The different kinds of birds feed on a wide range of plants, small animals like polychaete worms, molluscs and shrimps and fish in the estuary. (See Leaflet 9: The Life in the Estuary 2: The Food Web).
Many birds are only seen in the estuary for part of the year. Most of the waterfowl - the swans and ducks, use the estuary as a summer **drought refuge**. Australian Shelducks and Grey Teal arrive early in the summer as the lakes and swamps begin to dry up, while others like the Australian Shoveler spend the early summer in fresh water swamps where they breed and then arrive at the estuary late in the summer when the swamps are completely dry.
Large numbers of wading birds visit the estuary over the summer. Some, like Banded Stilts, come from their breeding sites in other parts of the State, while many are **migrants** who come to escape the harsh winter in their breeding grounds in the northern hemisphere. The estuary shallows offer them rich feeding grounds.

Black Swans (Photograph courtesy of the Department of Fisheries and Wildlife)

The birds

1. Waterfowl — geese, swan and ducks
(family: *Anatidae*)

Twelve of the nineteen species of waterfowl which occur naturally in Australia can be found in the Peel - Harvey estuary.
The Black Swan is the only native swan in Australia. Thousands of Black Swans visit the estuary, and the population has been estimated at up to 2,500, making it the most important estuary for swans in the South West. They graze on the vegetation on the banks and seagrasses in the shallows, and sometimes also eat juvenile fish.
There are no true geese in Australia, although the Maned Duck, which is occa-

sionally seen at the estuary, is sometimes referred to as the Maned Goose.

Several types of ducks use the estuary. The Freckled Duck is among the rarest of all waterfowl and it is occasionally seen loafing in quieter parts of the estuary. One group of eleven was observed at the southern end of Harvey Estuary. Australian Shelduck, with their colourful plumage, are seen in large numbers (sometimes several thousand) especially over the summer months. They graze on plants in the shallow water, and also eat insects and molluscs.

The Pacific Black Duck, possibly the commonest duck in Australia, also occurs in large numbers. It dabbles in the water for plants, insects and crustaceans, and also strips seeds from plants like sedges along the water's edge.

Grey Teal are common, over 8,000 having been recorded in one survey. They feed by dabbling and dredging in the mud for water plants, seeds, insects, mussels, and shrimps. Chestnut Teal have occasionally been seen with the Grey Teal, but only in small numbers.

Other waterfowl, including the Australasian Shoveler, Pink-eared Duck, Hardhead, and Musk Duck visit the estuary in smaller numbers in late autumn and winter, after their breeding swamps have dried out, or if food has run low.

Grey Teal (Photograph courtesy of the Department of Fisheries and Wildlife)

2. **Rails**

(family: *Rallidae*)

This large, widely distributed family includes crakes, rails, coots and swamphens. Only three have been recorded in the estuary. The Eurasian Coot, a nomadic bird, has been recorded throughout, and the Purple (Western) Swamphen lives among the dense reeds at the southern end of Harvey estuary, feeding on young reed stems, frogs and molluscs. The Australian Crake is sometimes seen in rushes at Island Point.

Purple (western) Swamphen (Photograph courtesy of the Department of Fisheries and Wildlife)

3. Waders

(Sub-order: *Charadrii*)

Many of the waders visiting the estuary are migrants from the northern hemisphere. They make the long journey south from their breeding grounds in Alaska, Japan, China and the USSR, flying as far as 9,000km to escape the harsh northern winter. Most arrive at the estuary from mid August to October. They feed in the shallows over the summer months, moulting and putting on extra fat to supply energy for the long journey back to their breeding grounds. Most leave between February and April.

The waders include sandpipers, plovers, stilts and stints.

One of the smallest, the Red-necked Stint, comes from northern Siberia to spend the summer months at Peel Inlet. Flocks of thousands feed in the shallow margins uttering twittering sounds as they run about picking up small invertebrates.

Black-winged Stilt (Photograph courtesy of the Department of Fisheries and Wildlife)

Other waders seen in large numbers are the Sharp-tailed Sandpiper which disperses widely from its breeding grounds near the Arctic Circle, and the Greenshank which comes from northern Europe and Asia. Sharp-tailed Sandpipers were once common in the Swan River estuary but they are now seldom seen there, so the Peel estuary is an especially important habitat for them.

Curlew Sandpipers and Red Knots can sometimes be seen in hundreds over the summer. The Curlew Sandpiper's long, downward-curving beak allows it to feed in deeper water. It wades out and inserts its beak into the mud or sand, searching for small invertebrates. Another migrant from Siberia is the Eastern Curlew. It too has a long bill to probe for worms and crabs and can be seen eating small crabs in the entrance channel. Peel Inlet is one of the few places in the south of the State where Eastern Curlews can be reliably seen.

Another wader regularly seen at the estuary mouth but not often elsewhere in the estuary is the Large Sand Plover. These birds come mainly to the north coast from central and eastern Asia, but a few come further south.

The Pectoral Sandpiper, Long-toed Stint and Ruff are regular migrant visitors to the estuary and nearby muddy lakes. Their numbers are not great, but they are uncommon in Australia and this estuary is important for them.

Some of the waders are not trans-equatorial migrants. They breed in Australia, but they too, often travel long distances from their breeding grounds. Banded Stilts breed in large numbers on inland salt lakes and visit the estuary in their thousands over the summer. Nomadic Black-winged Stilts and Red-capped Plovers, which breed locally, are also very numerous over the summer months.

4. Herons, egrets, ibises and spoonbills

(Order: *Ciconiiformes*)

These birds are grouped together because they are all long-legged, long-necked wading birds. They can feed in deeper water than most of the waders.

White-faced Herons nest singly in trees and paddocks, not necessarily near water. They visit the estuary to feed on crustaceans and fish. They also eat frogs and occasionally reptiles and small birds.

Great Egrets breed in colonies. There are only a few colonies in the South West, such as those at Lake Toolibin and Australind, and hence their survival here is cause for concern. They visit the estuary to feed, waiting quietly in the shallows to dart their beaks into the water to catch small fish, crabs and prawns.

Little Egrets also wade in the shallows searching for prey. Sometimes they shuffle a foot in the mud to stir small animals into movement. Little Egrets are also rare in the South West and although they are only seen in small numbers in the estuary — perhaps ten birds — this is the most important area for them in this part of the State.

Glossy Ibises, Sacred (White) Ibises, Straw-necked Ibises and Yellow-billed Spoonbills are also seen in small numbers. They are usually found in fresh water swamps where they feed as the water level drops over the summer, exposing food in the mud. When the swamps fill up again in winter, some of the birds move to the estuary to feed. Ibises probe into the sand or mud in the shallows, while spoonbills sieve the mud and water through their beaks to get molluscs and other small animals.

White-faced Heron, Great Egrets and Silver Gull (Photograph courtesy of the Department of Fisheries and Wildlife)

5. Grebes
(Family: *Podicipedidae*)

Grebes are diving birds, with streamlined bodies and lobed feet which make them very manoeuverable in the water. They chase their prey — fish and invertebrates — underwater.

Three species of grebes occur in Australia and all of them are found in the estuary — the Great Crested Grebe, Hoary-headed Grebe, and Australasian Grebe.

Australasian Grebes are less common than Hoary-headed Crebes which prefer large open bodies of water, feeding among sparse weed or on the bare bottom. Crested Grebes dive in open, clear water, pursuing fish up to 20cm long.

6. Pelicans, darters and cormorants
(Order: *Pelecaniformes*)

These birds, like the grebes, are mainly fish eaters. They belong to an ancient order of mainly marine birds which have a fossil record going back many millions of years. There are seven Australian species, six of which are found on the Peel - Harvey estuary.

The Pelican is the largest bird on the estuary, standing about a metre high. It has a long beak and huge throat pouch. Pelicans co-operate to catch fish by swimming in formation, driving fish into the shallows where they scoop them out with their pouches. They sometimes follow fishermen, waiting for the rejected cobbler heads, and their throat pouches often bear the scars of stings from the cobbler's painful spines. The pelicans seem to develop an immunity to the poison.

Darters nest in colonies in fresh water swamps in the reserve south of Austin Bay and in a nearby private sanctuary. They feed along the rivers and in the estuary, especially during the summer and early winter. Darters swim almost wholly submerged to stalk their prey — mainly fish, which they catch by darting their head forward and spearing with the sharp beak. Most birds oil their feathers so that they are not wetted by water when they swim and air is trapped in the plumage. Darters and cormorants do not have water-repellant plumage so they can swim freely underwater to chase their prey without being bouyed up by trapped air. In consequence they have to dry out their feathers again before they can fly, and darters can often be seen standing with wings spread out to dry them in the sun.

Great (black) and Pied Cormorants also fish in the estuary. Pied Cormorants nest on islands in Shoalwater Bay, and visit the estuary to feed on fish and crustaceans. Like Darters, they swim underwater to catch their prey and may stay submerged for half a minute or more. They are sometimes blamed for taking commercial fish, but the Great Cormorant is probably the only Cormorant that could take significant amounts of fish. It is not very common and probably does not have much impact on the fishing industry. Nevertheless, professional fishermen have permission from the Department of Fisheries and Wildlife to destroy Great and Pied Cormorants caught in the act of removing fish from nets.

Two smaller cormorants, the Little Black and Little Pied Cormorant, nest in the fresh water swamps to the south of Austin Bay. They catch small fish and crustaceans in the estuary. The Little Pied is probably more common, over seven hundred having been counted in one survey.

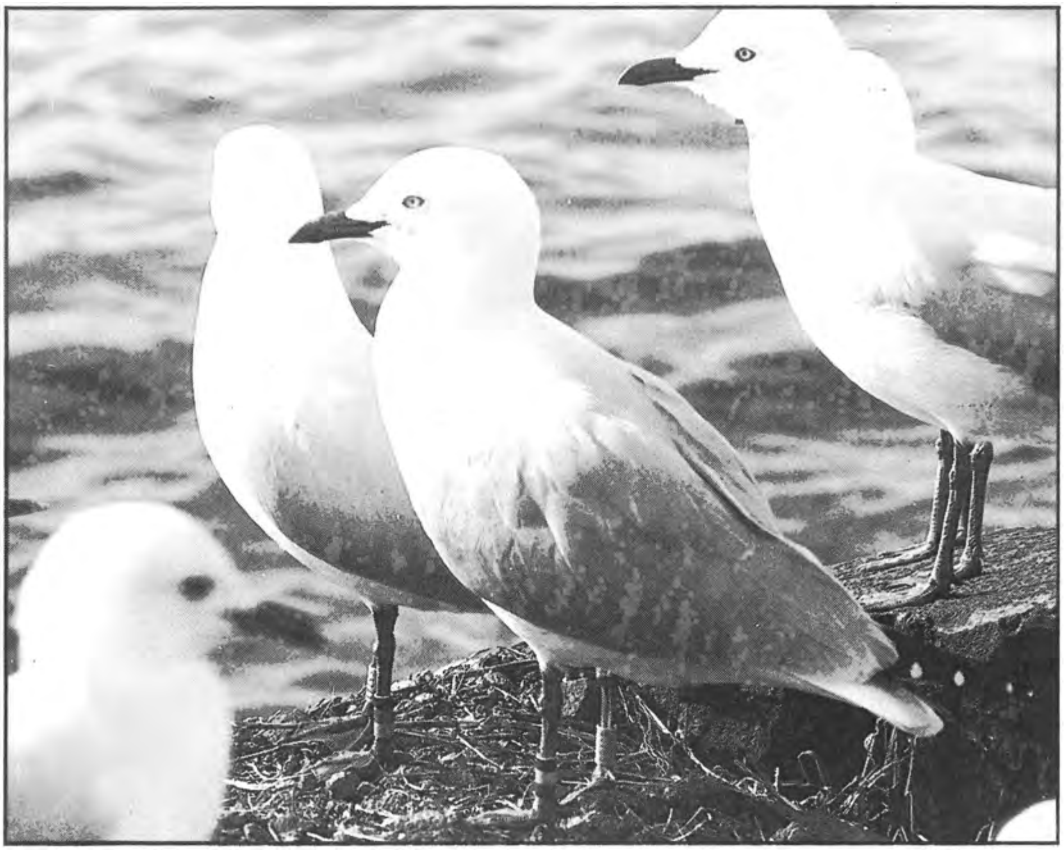
Little Black Cormorants (Photograph courtesy of the Department of Fisheries and Wildlife)

7. Gulls and terns
(Family: *Laridae*)

Silver Gulls, the common sea-gull in Australia, are numerous in the estuary throughout the year. They nest mainly on offshore islands, feeding on crustaceans in the masses of weed along the shores, and scavenging scraps. Sometimes they "puddle" their feet in the wet sand to find small invertebrates. Over three thousand gulls were counted in one survey in eastern Peel Inlet in one day.

Whiskered Terns breed in colonies in inland fresh water swamps. They visit the estuary to feed by hovering above the water for insects, and occasionally diving for fish. They are uncommon in the South West and the estuary is the most important area for them. Caspian Terns are also seen in small numbers diving for fish, as are Roseate, Fairy and Crested Terns which occasionally visit from beaches and offshore islands. White-winged Terns are rare in the South West but occur consistently in small numbers at the estuary. Another tern from the northern hemisphere, the Common Tern, is also seen occasionally.

8. **Kites and hawks**
(Family: *Accipitridae*)
Large White-bellied Sea-Eagles are sometimes seen fishing in the Inlet. They are skilled hunters, catching fish, small birds like ducks and juvenile Black Swans, and mammals such as rabbits. Whistling Kites take fish, carrion and occasionally young birds. Marsh (Swamp) Harriers hunt for small waterbirds like grebes and ducklings in the reeds.



Silver Gulls (Photograph courtesy of John Ottaway)

Research on waterbirds

The Department of Fisheries and Wildlife has conducted detailed studies of pelicans in the estuary and has made a number of counts of all waterbirds.

These counts have been followed by regular surveys of the eastern part of Peel Inlet by volunteer observers working for the Royal Australasian Ornithologists Union. Data has been collected since 1982 and has provided invaluable assistance to the Department in the management of nature reserves in that area. Volunteers have included members of the local branch of the Naturalists' Club.

The RAOU has also searched the estuary for waders as part of its programme of annual national counts and again, local residents have assisted this survey.

Birds and the phosphorus cycle

The birds, and especially increased numbers of pelicans, have sometimes been blamed for the algal problem. However, birds certainly take out of the estuary more phosphorus in fish and other fauna than they ever put into it in their droppings. For example, most of the numerous cormorants roost away from the estuary, fertilizing the trees on which they roost.

No doubt birds help in a small way to recycle phosphorus to algae, but all the birds on the estuary have between them only about one tenth of a tonne of phosphorus in their bodies, the fish perhaps ten tonnes, and algae and other plants over 100 tonnes. An average of 150 tonnes of phosphorus comes from the rivers each year; so the birds can hardly be credited with doing much to add to the phosphorus supply.

Birds recorded at the Peel - Harvey Estuary
(m = migrant)

Great Crested Grebe	*Podiceps cristatus*
Hoary-headed Grebe	*Poliocephalus poliocephalus*
Australasian Grebe	*Tachybaptus novaehollandiae*
Australian Pelican	*Pelecanus conspicillatus*
Darter	*Anhingar melanogaster*
Great Cormorant	*Phalacrocorax carbo*
Pied Cormorant	*Phalacrocorax varius*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Little Pied Cormorant	*Phalacrocorax melanoleucos*
Pacific Heron	*Ardea pacifica*
White-faced Heron	*Ardea novaehollandiae*
Cattle Egret	*Ardeola ibis*
Great Egret	*Egretta alba*
Little Egret	*Egretta garzetta*
Rufous Night Heron	*Nycticorax caledonicus*
Glossy Ibis	*Plegadis falcinellus*
Sacred Ibis	*Threskiornis aethiopica*
Straw-necked Ibis	*Threskiornis spinicollis*
Royal Spoonbill	*Platalia regia*
Yellow-billed Spoonbill	*Platalea flavipes*
Black Swan	*Cygnus atratus*
Freckled Duck	*Stictonetta naevosa*
Australian Shelduck	*Tadorna tadornoides*
Pacific Black Duck	*Anas superciliosa*
Grey Teal	*Anas gibberifrons*
Chestnut Teal	*Anas castanea*
Australasian Shoveler	*Anas rhynchotis*
Pink-eared Duck	*Malacorhyncus membranaceus*
Hardhead	*Aythya australis*
Maned Duck	*Chenonetta jubata*
Blue-billed Duck	*Oxyura australis*
Musk Duck	*Biziura lobata*
Australian Crake	*Porzana fluminea*
Purple Swamphen	*Porphyrio porphyrio*
Eurasian Coot	*Fulica atra*
Grey Plover (m)	*Pluvialis squatarola*
Hooded Plover	*Charadrius rubricollis*
Large Sand Plover (m)	*Charadrius leschenaultii*
Red-capped Plover	*Charadrius ruficapillus*
Black-fronted Plover	*Charadrius melanops*
Black-winged Stilt	*Himantopus himantopus*
Banded Stilt	*Cladorhynchus leucocephalus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Ruddy Turnstone (m)	*Arenaria interpres*
Eastern Curlew (m)	*Numenius madagascariensis*
Whimbrel (m)	*Numenius phaeopus*
Little Curlew	*Numenius minutus*
Wood Sandpiper (m)	*Tringa glareola*
Grey-tailed Tattler (m)	*Tringa brevipes*
Common Sandpiper (m)	*Tringa hypoleucos*
Greenshank (m)	*Tringa nebularia*
Marsh Sandpiper (m)	*Tringa stagnatilis*
Black-tailed Godwit (m)	*Limosa limosa*
Bar-tailed Godwit (m)	*Limosa lapponica*
Red Knot (m)	*Calidris canutus*
Great Knot (m)	*Calidris tenuirostris*
Sharp-tailed Sandpiper (m)	*Calidris acuminata*
Pectoral Sandpiper (m)	*Calidris melanotos*
Red-necked Stint (m)	*Calidris ruficollis*
Long-toed Stint (m)	*Calidris subminuta*
Curlew Sandpiper (m)	*Calidris ferruginea*
Ruff (m)	*Philomachus pugnax*
Silver Gull	*Larus novaehollandiae*
Whiskered Tern	*Chlidonias hybrida*
White-winged Tern (m)	*Chlidonias leucoptera*
Gull-billed Tern	*Gelochelidon nilotica*
Caspian Tern	*Hydroprogne caspia*
Common Tern (m)	*Sterna hirundo*
Roseate Tern	*Sterna dougallii*
Fairy Tern	*Sterna nereis*
Crested Tern	*Sterna bergii*
Whistling Kite	*Haliastur sphenurus*
White-bellied Sea-Eagle	*Haliaeetus leucogaster*
Marsh Harrier	*Circus aeruginosus*
Little Grassbird	*Megalurus cyaneus*

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Department of
Conservation and
Environment

PEEL – HARVEY ESTUARY PROGRESS

BULLETIN No. 146

NO 11
AUGUST
1985

MANAGING THE ALGAL PROBLEM: HOW WILL THE ESTUARY CHANGE?

The Recommended Strategy for Management:

In May, 1984, following about seven years of studies to determine the cause of the excessive algal growth in the estuary, and ways to manage it, the Department of Conservation and Environment released a report outlining a combination of management measures considered to offer the best solution to the problem (see Department of Conservation and Environment, Bulletin 170 and Bulletin 146, Leaflet 7). These measures, the 'preferred strategy', consist of:

- **Control measures** to relieve the nuisance of the algae collecting on the shore. These include weed harvesting and cleaning up the beach.
- **Preventive measures** to attack the cause of the problem by reducing the amount of phosphorus available for algal growth to about 30% of the present level. These measures aim to reduce the input of phosphorus to the estuary by modifying agricultural practices (especially fertilizer use) on the coastal plain, and increase the loss of nutrients to the sea by construction of the Dawesville Channel.

  A number of other 'supplementary measures' with the potential to help in solving the problem were also suggested.

At that time, however, it was difficult to predict with any certainty how adopting these measures would change the estuary. In particular, further monitoring of the effectiveness of the catchment fertilizer program was needed to see how the real drop in phosphorus loss to the estuary matched the predictions. More detailed mathematical modelling of how the proposed Dawesville Channel would affect water movement was needed to ensure that there would be no adverse effects on the estuary and so that predictions could be made about associated changes in plant and animal habitats.

The results of these and other studies are now complete and better predictions can be made about how the proposed management measures will affect the algae and the estuary itself.

An Environmental Review and Management Programme (ERMP) has been prepared to expose the management strategy for the estuary to public review and comment. If Government decides to proceed to the feasibility stage of investigation into the Dawesville Channel a Stage 2 ERMP will also be produced and subjected to public review.

This leaflet deals with the predicted changes in the estuary should the preferred management strategy, including the Dawesville Channel, proceed.

What can the management measures achieve?

The condition of the estuary has deteriorated progressively over the last 20 to 30 years as increasing amounts of phosphorus have poured in to fertilize algal growth. The management strategy aims to reverse this deterioration by reducing the amount of phosphorus available to the algae.

The 1984 research has shown that the fertilizer management program in the catchment will reduce the amount of phosphorus entering the estuary by 20 to 40% in about 3 to 5 years. This will help, but by itself will not be enough to solve the algal problem. There will be a further reduction in the long term (10 to 15 years) as excess reserves of phosphorus in the soil are used up, halving the present input, but even this is not expected to solve the problem.

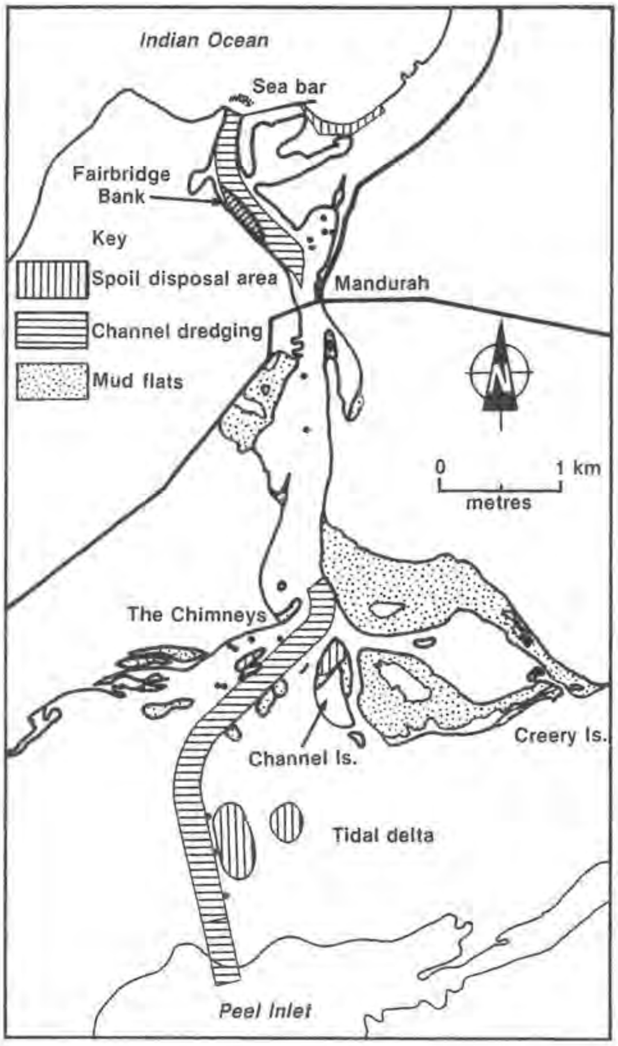
A number of other measures, including preventing phosphorus runoff from further clearing and drainage and from sources such as piggeries, or reducing runoff by planting trees (*Eucalyptus globulus*) for wood chipping, and spreading bauxite residue on some sandy soils, could also reduce phosphorus input in the long term.

Thus, although the catchment management measures can achieve a significant reduction in phosphorus input, a speedy solution to the algal problem requires other measures.

The modelling studies have confirmed that the proposed Dawesville Channel will improve flushing, and reduce the amount of phosphorus that stays in the estuary, so that it will reduce the algal nuisance to acceptable levels within 5 years. As a bonus, the modelling shows the channel will make estuary water more saline and so unfavourable for *Nodularia* growth.

Widening and deepening of the Mandurah Channel from the sea to the deep water of Peel Inlet will also improve flushing of Peel Inlet, but by itself it will not cure the weed problem and would have little effect on Harvey Estuary and the *Nodularia* blooms. In conjunction with the Dawesville Channel it would yield a greater improvement in flushing than the Dawesville Channel alone.

The Department of Marine and Harbours has proposed a dredging programme for the Mandurah Channel, both downstream of the Mandurah bridge (and including the ocean entrance) and upstream into Peel Inlet. These channel improvements would increase tidal flow between Peel Inlet and the sea by 25 to 30%. This proposed programme is currently the subject of a Public Environmental Report.



What will happen to the algae?

Once the Dawesville Channel is open, the *Nodularia* blooms will cease except perhaps under exceptional circumstances and at the southern end of Harvey Estuary. If they do occur they will be smaller and of shorter duration, because the water will be too saline for *Nodularia* to grow well and there will be too little phosphorus to support the blooms.

The weed growth in Peel Inlet will take longer to respond to this change. Over the years a large store of phosphorus has built up in the estuarine sediments and this will continue to fertilize the weed for some time to come — how long is difficult to predict. The improved flushing will result in clearer water, and this could make conditions even better for weed growth for some years, until the sediment phosphorus store runs down. The suggestion of removing the sediment store by dredging was examined, but was found to be quite impractical. However the possibility of rapidly reducing the availability of this phosphorus to plant growth by applying a chemical, nitrate, to the surface sediments is being investigated.

Until the weed growth responds to the reduced phosphorus supply, weed harvesting and beach clean-ups will be needed to keep the beaches acceptably free of weed.

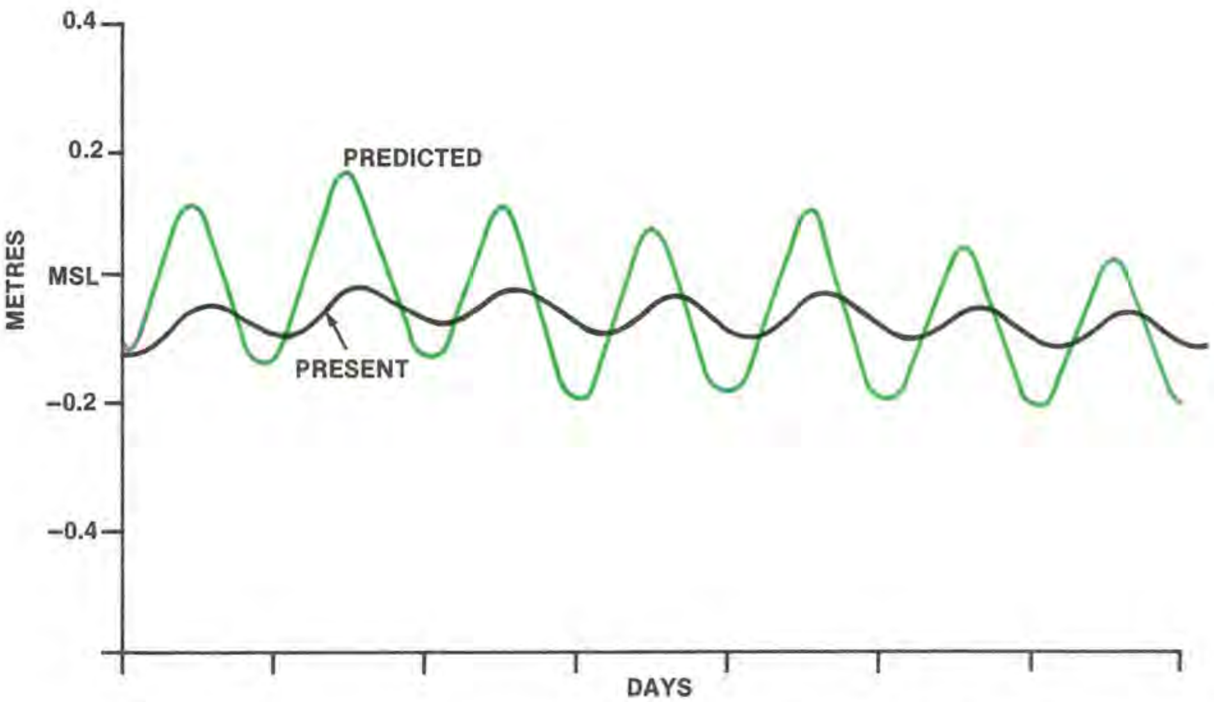
What other changes will there be?

The management measures will make the estuary less eutrophic (rich in nutrients), and so reduce the algal growth, but there will also be other changes.

The increased exchange of water with the ocean through the Dawesville Channel will cause changes in salinity, tidal movements and water clarity as well as in nutrient levels. These in turn will change the environment for plants and animals.

Tides

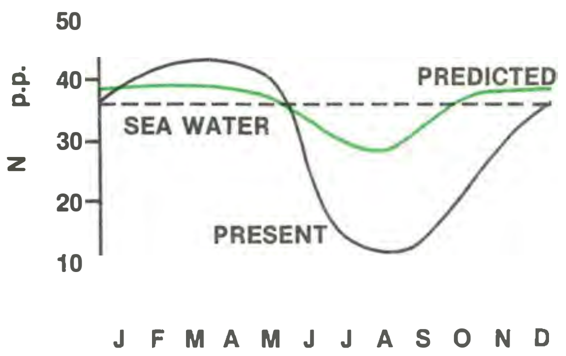
Modelling studies have shown that with the Channel, the present small daily tide will increase to up to 40–45% of coastal tides with a maximum range of 0.45 m though seldom more than 0.3 m. The extreme range of water level will also be slightly greater, big tides taking water 0.2 m higher and lower than at present. There will be no change to the average water level which is the same as in the sea. Probably the most noticeable difference will be that the nearshore shallows will be exposed more often than at present but only for a few hours instead of for several days at a time as sometimes happens now. One important bonus will be that flood water will get away faster.



A typical summer tide in the estuary, observed and predicted with the Dawesville Channel. Heights above and below mean sea level (AHD).

Salinity

The estuary will no longer experience the extreme salinities that it does now. Both Harvey Estuary and Peel Inlet will become more "marine". Only near the mouths of the rivers will the water ever be fresh, and in summer it will only be slightly more salty than the sea.



Seasonal salinity cycles in Harvey Estuary, present and predicted with Dawesville Channel.

Nutrients

The increased exchange of water with the ocean will result in lower nutrient levels as nutrient-rich estuary water is exchanged with low-nutrient sea water.

Water Clarity

More sea water coming into the estuary and less growth of microscopic plants (diatoms and *Nodularia*) in the water, will make the water clearer. Harvey Estuary will still be murkier than Peel Inlet because of the fine sediment suspended in the water, but here too the water will become progressively clearer.

Estuarine Life

It is impossible to predict exactly how these changes will affect all the plants and animals, but a careful study has been made based on what we know of their biology, and on what lives in other estuaries such as Leschenault Inlet, where the salinity and tides are much as the Peel-Harvey estuary is expected to be.

Plants

The wetland vegetation around the shoreline will benefit from the more regular tidal inundation and the samphire plants may slowly extend into areas where previously they could not survive. Seagrasses also will benefit in several ways. Clearer water will allow them to grow better and to extend into deeper water in Peel Inlet and to establish in Harvey Estuary, although there may be some loss of seagrass beds in the shallows of Peel Inlet when they are more often exposed by the tides. Seagrasses afford good shelter for juvenile fish and the small animals on which many of the fish and birds feed, and they are also food for swans and many kinds of ducks.
Like the problem algae, the diatoms which now cloud the water in spring will decline because of lower nutrient levels in the water. Other kinds of diatoms which grow on the bottom get their nutrients from the sediments, and will benefit from the clearer water. There will therefore still be abundant food for the tiny animals and fish which feed on microscopic plant life.

The seagrass, *Halophila ovalis*.

The seagrass, *Ruppia megacarpa*.

Animals

With the more marine conditions and the expected changes to the plant communities there are bound to be changes to the animal life. Other marine species which cannot tolerate the present salinity extremes will live in the estuary, and some of the present species may not be as common as they are now. However the abundance of the small bottom-living animals, and hence the food supplies for larger animals like fish, crabs, prawns and birds, should not be greatly affected.

The change from weed algae to seagrasses will also change the environment in which many small animals live. It is difficult to see how this will affect them, but it is not expected that there will be any great change.

The Fishery

The new channel to the ocean will provide an additional entrance for blue manna crabs, king prawns and fish which come into the estuary from the sea.

The more marine conditions will allow a greater variety of fish to use Harvey Estuary throughout the year. Most marine fish, including the commercially important yellow-eye mullet and tailor, only spend part of their lives in the estuary, and will be able to stay longer. The blue manna crab should be able to live in all parts of the estuary for most if not the whole year. It is possible that the salinity changes may not suit sea mullet, or king prawns.

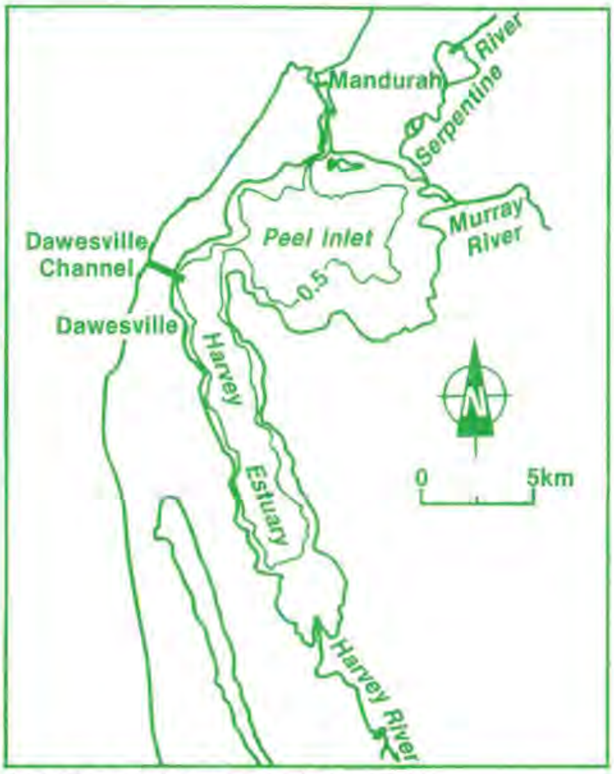
The weed provides shelter for fish and a habitat for the small animals on which they feed, and has probably contributed to increased catches over the period when weed has been abundant in the estuary. Solving the weed problem too efficiently might therefore be expected to cause a drop in fish numbers, but luckily the seagrasses which will eventually replace the weed beds will serve a similar function, without causing the same problems as decaying weed.

The fishery should benefit directly from the reduction in *Nodularia* blooms, both because the clearer water will make it easier to haul nets, and because greater numbers of fish will be able to stay in areas previously affected by *Nodularia*. At present many small fish, and the small animals on which fish feed, die when the *Nodularia* blooms collapse, and bigger fish and crabs have sometimes been killed. Without *Nodularia* there should be no such deaths in the future.

Birdlife

Most birds should be little affected by the changes to the estuary. The tidal flats, which are an important feeding area for many, will, if anything, increase. Most of the plants and small animals on which the birds feed will remain abundant. Waders will have to adjust their feeding patterns to daily tidal fluctuations.

Resident waders, such as Banded Stilts which are usually found in inland non-tidal wetlands, may lose some feeding sites because of the more frequent tides; there may also be a reduction in suitable roosting sites for waders and other birds like pelicans and cormorants which roost on sandy cays and sand bars. Ways of managing these possible problems are being considered.



Location of the proposed Dawesville Channel.

What is a healthy estuary?

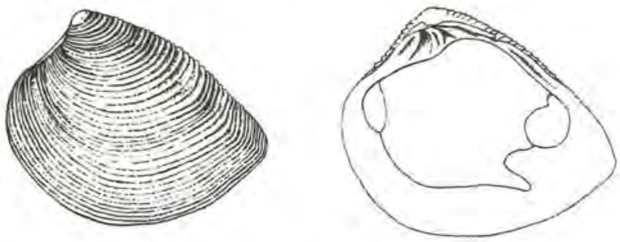
Two other local estuaries have undergone changes similar in effect to the Dawesville Channel. Leschenault Inlet had a channel cut through to the sea in 1951, and the Swan River had rock and sand bars at the mouth which were removed in the 1890's. There is little doubt that both systems have changed but they are still healthy, productive estuaries.

What do we mean by healthy? Do we want the Peel-Harvey estuary to be as it was 40 years ago, before the algal problems, or in the 1800's, before man's impact, or perhaps even 1000 years BC? What is wanted is an estuary in balance, where the primary productivity — plant growth — does not outstrip the growth of the animal populations which eat vegetation, and there is not an excess of decaying plant material.

The estuary has changed considerably during its history, since it was flooded by rising sea levels 6-7000 years ago. For a time it was a marine embayment, rather like Oyster Harbour is today. The extensive shell beds along the Mandurah Channel and in Peel Inlet are testimony to the abundance and diversity of more marine molluscs present at that time. One, the bivalve *Katelysia* was especially common, just as it is now in Princess Royal Harbour and a few estuaries on the south coast. Then 3000 to 4000 years ago exchange with the ocean became obstructed and the mollusc and other invertebrate life in the estuary was reduced to a few, mostly small, species which were adapted to the new conditions, and they have flourished. From that time until 1967, when the training walls at the mouth were constructed, there were times when exchange with the ocean was blocked completely, sometimes for months at a time.

Human impact began with drainage of the coastal plain from 1900, damming of the hills catchments and especially with the increasingly large input of phosphorus from fertilizers since 1945. The estuary, with its one restricted opening to the sea, was vulnerable and heading towards eutrophication long before the deterioration became obvious in the accumulations of weed.

The management measures will not simply reverse the clock 30 or 40 years to the time when there was no weed problem, it is too late to do that. They will make the estuary a different, more marine, healthy system which will be more resilient to the increasing pressures from human use.



Shell of *Katelysia scalarina* actual size.

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