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Fish and Exploited Crustaceans of the Swan-Canning Estuary

BY

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FISH AND EXPLOITED CRUSTACEANS OF THE SWAN-CANNING ESTUARY

*R.C.J. Lenanton

I INTRODUCTION

Fishes of the Swan-Canning estuarine system are typical of those found in other lower west coast estuarine systems of Western Australia. Species representing three families of elasmobranchs, several of which are commercially important, twenty families of teleosts, and two families of crustaceans (Table 1) commonly occur in this estuarine system. The many other species which occur less commonly in the Swan-Canning estuary are mostly members of the additional families listed in Table 1.

The information contained in this document was made available for use by the authors of the following two publications :-

Forbes and Fitzkardinge (1977) Swan and Canning Rivers Activity Study. Report prepared for the Department of Conservation and Environment, Perth, Western Australia.

Riggert, T. (Ed) (1978). The Swan River Estuary - Development Management and Preservation (Govt. Printer: Perth, Western Australia).

II UTILISATION OF THE ESTUARINE HABITAT

All of the different species of fish which have been recorded from the Swan-Canning estuary can be included in one of the following three categories, on the basis of how they mostly utilise this estuarine environment.

1. <u>A PERMANENT BREEDING AND NURSERY HABITAT</u> (Figure 1)

   Species typical of this group include black bream, cobbler, Perth herring, some flathead and flounder species, river garfish, yellowtail grunter, some of the non-commercial species such as the hardy head, gobbleguts, and some of the gobies. The only commercial crustacean in this group is the greasyback, school or common river prawn. It should be noted that a number of these fish, e.g. cobbler, flounder, and flathead are also capable of reproducing and living entirely outside the estuary in marine embayments such as Cockburn Sound. Other species such as black bream and Perth herring are capable of making excursions into similar areas, mainly in response to winter flood conditions. However, irrespective of the above cases, all species in this group are capable of reproducing and living entirely within the estuarine system. Some, such as the hardyhead, gobies, and cobbler, have rather specialised breeding habits which help to make them well adapted to living in such extreme habitats. These produce relatively few eggs, but take rather better care of them than most fish. Hardyheads attach their eggs to seagrass fronds, and gobies actually build nests under stones and other objects attaching their eggs to the inner surfaces of their nests (Lenanton 1977). The cobbler is also thought to be a nest builder, although the precise details of the nest structure are unknown (Kowarsky 1975).

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2. A NURSERY HABITAT FOR JUVENILES (Figure 2)

Fishes in this group include the bulk of the most important commercial and amateur species. Species typical of this group include the mullets (sea and yelloweye), the whitings (King George, western sand, and trumpeter), silver bream, tailor, mulloway, some of the flatheads and flounders, sea garfish, striped perch (or trumpeter), roach, whitebait and anchovy, and the commercial crustaceans: blue manna crabs and king prawns. As outlined in Figure 2, they all utilise the estuarine habitat as a nursery area. Abundant food and shelter both from predators and from the more boisterous marine environment are important factors which encourage the utilisation of the estuaries by the young stages of many of these species. From research in other estuaries (Lenanton 1977) and preliminary work in the Swan (joint programme on fishes of the Swan by Department of Fisheries and Wildlife and Murdoch University), it is clear that the shallow banks, in particular the seagrass *(Halophila ovalis)* areas, are the most important nursery habitats for these fish, mainly because of the abundant supply of small invertebrate animals which are a principal source of food for these small fish (Thomson 1957, Wallace 1975). These banks are certainly more productive in terms of abundance of potential fish food than the deeper areas (Wallace, 1977) which is reflected in differences in the abundance and distribution of fishes inhabiting the two areas (Chubb, unpublished). However, blue manna crabs do appear to be one exception to the rule, large numbers being taken in the research samples from the deeper areas in the lower river during 1977.

It should be emphasised that the natural history pattern illustrated in Figure 2 is the one which could be expected during a year when a reasonable freshwater flush is experienced during the winter months. In years of reduced winter freshwater flushing, species such as trumpeter whiting, tailor, mulloway, and crabs may remain in the system all year, particularly in waters of the lower estuary which do not become fresh. Conversely, in years of prolonged heavy winter freshwater flushing, the above four species may be forced out of the system for long periods of the year.

3. AN OCCASIONAL FEEDING AREA FOR MATURING/MATURE ADULTS (Figure 3)

Species typical of this group include Australian herring and salmon, skipjack, blowfish, school whiting, scaly mackerel, pilchard (mulie), blue sprat, blue (common) mackerel, and most of the sharks and rays. Species in this group form only a minor part of the commercial and amateur catch from the estuarine system. Most of these species are more commonly caught in the marine environment, particularly in marine embayments such as Cockburn Sound, along coastal beaches and in waters around Rottnest Island. These species only venture into the lower estuary when the salinities are approaching those of seawater, i.e. usually in the summer months. However in abnormally dry years, they may remain in the system for a number of months, venturing far upstream into the tidal river. The blowfish is a good example of an animal from this group that is able to remain in the system for prolonged periods. Past research (Lenanton 1977) showed that this species did not reproduce in the Blackwood River estuary nor utilise the estuary as a nursery habitat during 1974/75. However, there was an above average freshwater flush during 1974. Under estuarine conditions during dry years therefore, blowfish may well be able to reproduce in the Blackwood River estuary or at the very least utilise the estuary as a nursery habitat, and therefore may more correctly be included under category 2, above. From the reported catches of this species by prawning parties in the Swan-Canning estuary, it is clear that the blowfish is able to make good use of this estuary during summer months. However the extent of its seasonal usage of the Swan-Canning estuary will not be known until the present research on fishes of this system is completed.

Having looked generally at the life histories of the common fishes of the Swan-Canning estuary, it is now appropriate to look at the factors which affect a fish species' utilisation of the estuarine habitat, or in other words, the reasons for assigning a particular species to one of the above three categories.

III NATURAL FACTORS WHICH AFFECT THE UTILISATION OF THE ESTUARINE ENVIRONMENT BY FISH

There are many natural environmental factors which collectively influence the manner and extent of either a fish's or crustacean's utilisation of the estuarine environment (de Sylva, 1975), the most important of these includes salinity, temperature, dissolved oxygen, turbidity, and available food and shelter (Lenanton 1977).

However, before looking at the effects of these factors in more detail, it must first be assumed that each species has achieved successful reproduction and larval survival (Stages 1 and 2, Figure 4), thereby making available suitable numbers of juveniles with the potential to utilise the estuarine environment and grow into stocks of exploitable adults. Given that this is so then the discussion of factors which affect the utilisation of the estuarine environment by the different species will be concerned both with the movement of fish between the estuary and the ocean (i.e. mostly fishes of Categories 2 and 3 above), and the distribution of fish once they are present in the estuarine environment. In this regard it should be noted that species of categories 2 and 3 that utilise the Swan-Canning estuary are always able to move between the ocean and the estuary through the permanent opening to the system. This is in contrast to many of the south coast estuarine systems where many of the same species of fish are denied permanent passage between the estuaries and the ocean by the periodic formation of bars of mobile sand across their various entrances.

Of the many factors mentioned above that influence the way in which a species utilises the estuary, salinity is considered to be most important. Obviously those species which utilise the estuary as a permanent habitat must be able to cope with the extreme seasonal variations in the estuary salinity from almost completely fresh in the winter to sea water or even slightly hypersaline conditions in the summer period. Fishes which are able to adjust to a wide range of salinities are known as euryhaline species.

The species of the second category which usually reproduce in the ocean and utilise the estuary mostly as a nursery habitat make best use of the estuary during the summer months when salinities approximate those of sea water. Species within this category are able to cope with varying degrees of dilution of their surrounding medium. Some species such as trumpeter whiting, whitebait, king prawns, and blue manna crabs are forced out of the estuary by the freshwater flush, while others such as sea and yelloweye mullet are able to live in the estuary all year. These different patterns of seasonal utilisation are reflected in the monthly commercial catch figures for those species. Sea mullet and yelloweye mullet are caught right throughout the year, whereas *whitebait, king prawns and blue manna crabs are taken mostly during the summer months. Osmotically blue manna crabs are unable to survive sustained exposure to waters of less than about $10^{o}/oo$ (Meagher 1971). Therefore a sustained winter freshwater flush would force them downstream into waters of tolerable salinity, either in the ocean or harbour area. There is no literature available reporting the osmoregulatory ability of whitebait and prawns, however, it is most likely that it is also the sudden drop in salinity which is an important factor in forcing these species out of the estuary in the path of the winter freshwater flush. Certainly it is well documented that sea mullet are extremely good osmoregulators (Thomson 1966, Lenanton 1977). However even though mullet are not forced out of the estuary, they can be forced out of the riverine region of the system into the lower reaches by the velocity of a severe freshwater flush.

Fishes in the third category can only tolerate minor dilution of their external medium. They only venture into the estuary when salinities are around those of seawater, so most are brief summer visitors. Such species include skipjack, yellowtail, and blue sprat. Fish which can only live in water of seawater salinity are called stenohaline-marine species.

It should also be noted that there are freshwater fishes which cannot cope with any concentration of their external medium. These are called stenohaline-freshwater species. This component is virtually absent from the Swan. However, on one occasion during the peak of the freshwater flush, some minnows (Galaxiids) were taken in the upper reaches of the Canning River estuary. The freshwater catfish also falls into this category (Lenanton 1977), but none have yet been recorded from the Swan-Canning system.

*Both whitebait (*Hyperlophus vittatus*) and anchovy (*Engraulis australis*) are taken commercially, from the Swan-Canning estuary. Quite often both species are taken in the same catch. They are recorded in the statistics under Anchovy, however most of the annual catch would be whitebait.

Temperature is another important factor which affects the fish's utilisation of estuaries. Until recently it has been thought that tailor are forced out of the river by the first winter freshwater flush. However, during the 1976/77 summer, they were known to have left the Swan-Canning estuary well before the first freshwater flush. Indications were that falling winter water temperatures forced them out of the estuary into the warmer oceanic waters well before the winter freshwater flush. In reality, it could be that both lower water temperature or salinity could force the fish out of the estuary, depending on which of these factors was first to become unacceptable to the fish. So to be well adapted to living in an estuary a fish must be both euryhaline and eurythermal.

The foregoing discussion has mostly been concerned with the movement of fish between the estuary and the ocean. However, these same factors influence the behaviour and distribution of fish within the estuary. Shallow semi-enclosed embayment areas or particularly isolated bodies of shallow water in the Swan-Canning estuary such as Alfred Cove may tend to become slightly hypersaline and considerably warmer in the still, hot periods of the summer, or conversely markedly cooler and perhaps of lower salinity than the main body of water in the estuary during winter. In both these situations fish which normally live on these shallow banks may be forced into the deeper areas of the main body of the estuary.

Similarly there are certain areas, such as the whole of the Swan-Canning estuary basin, where deep pockets of saline water tend to become deoxygenated during early winter when they are trapped beneath the surface layer of freshwater from the first winter flush. Certain species of fish such as cobbler which need the higher salinity water to survive eventually die, because by remaining in the salt water pocket they die from lack of oxygen. However if they choose to leave the high salinity pocket, they also perish, not because of low oxygen, but because they cannot cope osmotically with the lower winter salinity of the surrounding water (Kowarsky 1975).

There are other situations which can result in deoxygenation of estuary waters. The macrophytic algae and seagrasses of the relatively shallow weeded areas photosynthesise during the day resulting in oxygenation of overlying water. However during darkness hours, the plants respire, causing a considerable drop in the dissolved oxygen levels of overlaying water, sometimes to levels that are unacceptable to fish. It is generally accepted that levels below 5 mg/l can cause changes in behaviour, while levels below 3 mg/l can cause death (Perkins 1974).

Other factors such as turbidity, particularly that generated by winter flushing, or by surface to bottom mixing of water over shallow banks by persistent strong wind, may also affect the distribution of the fish within the estuary. However, naturally occurring turbidity probably would not pose a serious threat to estuarine fish, because from an evolutionary viewpoint, they should be well adapted to such situations.

Available food, and shelter from predators and the boisterous conditions of the open ocean, are also most important factors which influence the utilisation of the Swan-Canning estuary by many species of fish and crustaceans. This protected estuarine environment, rich in nutrients, supports an abundant supply of small macrobenthic invertebrate animals, such as shrimps, polychaetes (worms), small molluscs (Chalmer, Hodgkin and Kendrick 1976), and zooplankton organisms, such as copepods. Most of these invertebrates only occur within the estuarine environment. The many fish species, particularly the juvenile stages depend on these animals as an essential source of food. A simplified illustration of this estuarine food web is presented in Figure 5.

In addition to the good supply of small macrobenthic organisms, the estuary is also rich in organic detritus (decaying animal and plant material) which is utilised by species such as sea mullet and Perth herring. These fish are known as iliophages. They derive most of their nutrition from the organisms such as bacteria which are breaking down the detritus.

Recent observations in the Swan estuary (Wallace 1977) have revealed that macrobenthic invertebrate animals are much more abundant on the shallow banks than in the deep muddy areas of the estuary. Over the same period, a general survey of fishes of the Swan-Canning estuary (Chubb unpublished) revealed that fish species, particularly juvenile stages, were more abundant on these shallow banks than in the deeper areas. As mentioned earlier the blue manna crab did provide one of the few exceptions, being more abundant in the deeper areas. Clearly the fish found in the shallow banks are utilising the abundant supply of food which is found there. A similar situation has been shown to exist in the Blackwood River estuary (Lenanton 1977).

IV HUMAN ACTIVITIES AFFECTING THE ESTUARY AND ESTUARINE FISH

The preceding section has been concerned with the manner in which the most important natural environmental factors affect fishes' utilisation of the Swan-Canning estuary. However, as the human population increases, the resultant increase in multiple usage of the estuary and its environs imposes additional stresses which are superimposed on the already naturally changing environment, and the animals living within it. The reaction of these estuarine animals to this additional stress depends largely on the type and severity of the stress. Responses can range from behavioural changes to actual death.

There are many man-made estuarine disturbances which affect estuarine fish populations (Lenanton 1974, Hodgkin 1974). The most important ones include (i) dredging, filling and mining; (ii) alteration to river catchments such as land clearing which affects the quantity and quality of runoff; (iii) construction of barrages and dams across rivers which alter the natural seasonal flow of rivers entering estuaries, thereby affecting the biology, particularly the breeding biology of some fishes, such as those whose spawning migration takes them from or to the upper reaches of the estuarine system, i.e. catadromous and andromous species and (iv) the use of estuaries as receptacles for industrial, agricultural and municipal wastes, which can lead to contamination of fish, and eutrophication of waterways.

There are many other minor changes, such as the erection of structures such as jetties, small boat marinas, and removal of logs and other natural refuges which effectively change and in some cases destroy natural foreshores. One such example is the construction of the retaining stone wall around the natural foreshore of much of Perth and Melville waters.

These disturbances and their effect on fish are too numerous to be discussed here in detail, however in discussing several of the major ones, it is important to realise that the effects of individual developments should be considered collectively, and not in isolation.

This principle applies particularly to dredging and filling activities which probably are the most common types of estuarine change instituted by man, having been practised in the Swan-Canning estuary for decades. Certainly such alterations in early years were performed by people who did not appreciate the biological significance of the areas they were altering. However over recent years the accumulation of knowledge, and development of appropriate expertise, should enable much more informed judgements to be made regarding such proposals. Dredging and filling activities destroy the shallow banks and naturally vegetated foreshores which are so important to the survival of fish and commercial crustaceans of the Swan-Canning estuary. Each square metre of bank that is reclaimed is one less for the present assemblage of fish to have available for their use, and is a further step towards a reduction in the potential utilisation of the estuary by these fish. Clearly some alterations must be made and compromise decisions must be taken on some proposed developments, usually in the form of conditions such as constraints on the development techniques or methods. This type of solution is probably only useful in situations where the proposed dredging development is in support of a finite structure, such as a bridge or jetty. However, in the case of dredging to accommodate a continually expanding need, such as boating and associated recreational activities, governments are faced with trying to find a solution to the problem of satisfying these demands using the basically finite area of water of the Swan-Canning estuary.

Assuming that these recreational needs of the community will continue to expand, then clearly dredging will only temporarily alleviate the problem of congestion in the Swan-Canning estuary. If dredging new areas of the estuary was considered to be the best solution, then ultimately the people of Western Australia may be left with an estuary which had been extensively dredged to accommodate the rapidly expanding boating activity; while the congestion problems experienced become as intense as those that prompted the first applications to dredge parts of the estuary. Such a sequence of dredging could severely alter the biological function of the estuary, possibly to the detriment of the vast numbers of people who would wish to participate in recreational fishing within the estuary.

So clearly, dredging in order to solve the boating congestion problem, is not compatable with the needs of the many species of fish and crustaceans that presently utilise such an environment. A more realistic solution may be to relocate some of this boating and associated recreational activity into the inshore oceanic waters where they could operate in protected embayments such as Cockburn Sound, or from marina developments like the one provided at Sun City.

There are other aspects of boating activities which pose problems for estuarine fish. Excessive use of power boats particularly in small enclosed bodies of water, can disturb sediment and invertebrate animals on shallow banks, on which the fish are so dependent and erode shorelines. By-products from fuel used in outboard motors can also cause tainting of the flesh of fish (Surber 1971).

Aside from the above problems of removal or alteration of essential shallow-bank juvenile habitat, dredging activities can pose many other problems for estuarine fish and crustacean populations (Lenanton 1974, EMAC 1976). An important indirect effect is the disruption to lower levels of the food web, such as the essential plant and invertebrate food supplies of fish; while some of the direct effects include those of dissolved oxygen depletion of estuarine waters, and changes in estuarine hydrology and topography. However, possibly the most important is the direct effect of natural suspended solids on fish. Studies with American estuarine fish have shown that lethal concentrations of sediment vary from species to species (O'Connor and Sherk 1975; Sherk, O'Connor and Neumann, 1975). Species which are normally associated with waters carrying a heavy load of suspended sediment are more tolerant than fish which feed by filtering plankton, and early life history stages are more sensitive than adults. Sublethal responses include increase in the oxygen carrying capacity of the blood, employment of greater gill surface area for gaseous exchange, and increased mucus production by the gills. When the mucus-sediment mixture is ingested by some species, it is possible that the low pH of the stomachs may cause adsorbed pollutants such as heavy metals or pesticides to be released and absorbed by the fish. The severity of these sublethal effects depends on the period of exposure to the suspended sediment.

It is of interest to note that the American juvenile bluefish (*Pomatomus saltatrix)* is "highly sensitive" to suspended solids (O'Connor and Sherk 1975). Tailor *(Pomatomus saltator)*, an almost identical species is one of the most common species of the Swan-Canning estuary, and a most important sport and commercial species. This species, together with yelloweye mullet, Australian herring and school whiting *(Sillago bassensis)* experimentally displayed a marked avoidance response to inert particulate material in suspension (Edmonds, unpublished).

Changes to catchments which affect the quality and quantity of water flowing into an estuary are also important. Extensive agricultural clearing has contributed greatly to the increased salinity of the Avon River (Kendrick 1976) which flows into the Swan. The increased salinity of water which flows into the Swan-Canning estuary will probably not affect the distribution of estuarine fish, because most are extremely good osmoregulators, though it may affect other life history stages, i.e. eggs and larvae. However increased salinity will obviously affect the freshwater fish component of the estuary so that, although they are only minor contributors to the total fish fauna, endemic species such as the galaxiids and pigmy perch could well suffer as a result.

Rivers provide pathways by which substances such as available nutrients, pesticides from agricultural activities and heavy metals from natural sources or industry are carried into estuaries.

Such substances may be transported to the estuary in a dissolved state. However, they also become adsorbed to suspended particulate material, particularly the colloidal size range, such as clay, and in this state are transported down rivers and into the estuary. In areas of the estuary where the fresher flood waters mix with the more saline estuary water, a considerable proportion of these suspended particles tend to flocculate and become deposited in the sediments (Phillips, 1972). A small proportion of the dissolved substances also remain in the estuary. However quantities of both particulate and dissolved material flow out to the ocean and may eventually be deposited in areas such as Cockburn Sound.

Alteration to the catchment of the Swan and its tributaries such as clearing, encourages soil erosion and leaching which results in increased levels of suspended particulate material moving down the rivers during times of flood. Thus the opportunity exists for increased loads of adsorbed nutrients, pesticides and heavy metals to be carried downstream to become deposited in the estuary sediments.

Wastes from industrial and municipal activities which find their way into estuaries either directly or via atmospheric fallout result in a further accumulation of undesirable substances in many of the world's estuaries (Perkins, 1974). Dissolved fractions are rapidly taken up into the biological food web, while much of the particulate matter, such as metal, pesticide or nutrient rich sewage sludge or dredge spoil, is deposited in the sediments.

The sediments and their interstitial water can either accumulate or release nutrients (Bricker and Troup, 1975), pesticides (Pionke and Chester, 1973) or heavy metals (Wolfe 1975). Exchange of the various nutrient elements across the sediment/water interface depends on many factors, such as the chemical reactions occurring in the sediment reservoir that take up material from or release it into the interstitial water, and the porosity of the sediment which influences diffusion across the interface (Bricker and Troup, 1975). Heavy metals also become remobilised and released from sediments. The presence of sulphide ions in interstitial water of the sediments influences the mobility of these metals. Insoluble metal sulphides are less mobile, than soluble ones within the interstitial water below the sediment/water interface of the estuary. However release into the overlying water depends on whether the metal sulphide compounds which become oxidised on contact with the estuary water are soluble, or precipitate in this overlying water (Thomson, Turebian and McCaffery, 1975). Disturbances of sediment as a result of both tidal and storm generated scouring, bioturbation, i.e. mixing by benthic infauna of the sediments, and other mechanical action also encourages the release of both nutrient elements and heavy metal compounds. The release of pesticides depends on their chemical characteristics, how strongly they are adsorbed, and the level of microbial activity, which is itself dependent on whether oxygenated or deoxygenated conditions persist in the sediments (Pionke and Chester 1973).

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These substances may be consumed directly by detritus eaters such as Perth herring, sea mullet or prawns, or indirectly via macro-invertebrate animals or rooted aquatic angiosperms which are eaten by fish.

Not all of these substances consumed by the above animals are assimilated. Those which are not utilised are returned to the sediments through the medium of faecal pellets. Juvenile fish have been shown to recycle heavy metals in estuaries in this manner (Cross *et al*, 1975). Substances are also returned to the sediment in the remains of dead animals and plants.

Excessive amounts of nutrients in estuarine waters are taken up by macrophytic algae and phytoplankton and can lead to eutrophication of waterways. The occurrence of this phenomenon in estuaries is well documented (Ketchum 1969; Carpenter, Pritchard and Whaley 1969). However some of the more important effects include changes in aspects of the ecology of estuarine fish such as the exclusion of some species in favour of others, production of physiological stress due to localised oversupply or depletion of dissolved oxygen (Fry 1969), or deaths due to blooms of toxic blue green algae.

Both polychlorinated hydrocarbons, e.g. DDT, and organophosphorus pesticides are used in Western Australia. Both can be extremely toxic to fish and crustacea (Keiffer, 1972, Butler, 1966, 1971), although fish are more sensitive to polychlorinated hydrocarbons, and crustacea to organophosphates (Butler, 1966). The organophosphorus pesticides are unstable, quickly degrading after application to relatively harmless by-products. Therefore they tend not to persist and their effects are restricted to the immediate area of application. In contrast the polychlorinated hydrocarbon pesticides and their chlorinated breakdown products are relatively stable; they persist for long periods, and display effects far from their original point of application (George, 1965). This is also true of heavy metals. Thus all these substances can accumulate in the estuary sediments and in the estuary food web, particularly in animals such as those fish which are at the top of the food chain (Figure 5). Their effects vary with different species of fish involved and depend on the particular type and concentration of the metals or pesticides involved (Perkins 1974). Certain doses of both pesticides (Butler 1966, Eisler 1971) and heavy metals (Perkins 1974) are toxic to fish and crustaceans. However lower doses may cause disruption to the normal behavioural (Davey *et al*, 1972) and natural history processes of these animals.

Finally, both pesticides and heavy metals may be a potential health hazard to people who consume contaminated animals (Perkins 1974).

Dumping and the release of effluents have been well controlled in the Swan-Canning estuary over past years, with the result that virtually no serious industrial discharge of this sort exists in the estuary. However, irrespective of the constraints placed on human usage of estuaries and their environs, there is bound to be some accumulation of substances such as nutrients, pesticides and heavy metals in the estuary sediments which are potentially dangerous to fish and man, in close proximity to a densely inhabited area.

V EXPLOITATION OF THE FISH

Estuarine fish are normally utilised in one or more of the following ways; they can -

(i) die either from natural causes or those generated by interference to the environment, and be devoured by scavenging organisms ranging from birds and other fish to bacteria;

(ii) be preyed upon directly by fish and birds;

(iii) be caught by man either professionally or recreationally.

This paper is concerned primarily with the human harvest of fishes, and the effects of this long term exploitation on annual levels of both commercial and amateur production.

The past history and present status of the fishery of the Swan-Canning estuary may be summarised as follows:-

1. LICENSED FISHERMEN (PROFESSIONAL AND AMATEUR)

During the period between the initial settlement of the State in 1829, and the introduction of the first fisherman's licence in 1899, everyone was free to catch fish in the Swan-Canning estuary for domestic use, barter or sale. From 1899 until 1905, those people who caught fish for sale, or who used a seine net to catch fish were required to hold a fisherman's licence. From 1905 until 1940, people who caught fish for sale by any means at all, or who owned a seine net, were required to hold a fisherman's licence. Thus up until 1940, amateur or domestic fishermen as they were then called who owned a net other than a seine to catch fish other than for sale, were not required to hold any sort of fisherman's licence.

From 1940-1949, anyone catching fish by means of any net whatsoever, was required to hold a fisherman's licence, irrespective of whether or not the fish were sold.

The first actual distinction between professional and amateur fishermen was formally made in 1949 by the issue of separate licences for professional and amateur fishermen. This distinction is still maintained at the present day (Lenanton, in prep.).

2. THE PROFESSIONAL FISHERY

The major commercial species taken are listed in Table 1. Monthly production data are available for all these species from 1952 up until the present day (Lenanton unpublished). The most important* species include sea mullet, cobbler, tailor, mulloway, flathead, crabs, and prawns, which are all utilised mainly as food; yelloweye mullet (and some sea mullet) and Perth herring which are caught mainly for rock lobster bait (Morgan and Barker, 1975); and whitebait

* Annual production is mostly over 1 000 kg.

which are mostly sold as angling bait. All the available annual production figures for these ten species, since the commencement of the licensed fishery in 1899, are presented in Table 2. In this regard it should be noted that the present system of monthly commercial fisherman's returns did not commence until 1941. Prior to this, production statistics were obtained from district inspectors' reports, processing and marketing returns and returns for fish despatched by rail.

During and immediately subsequent to World War 1, it was understandably difficult to obtain supplies of fresh food. The community relied to a great extent on the fresh fish supply from the Swan-Canning estuary. At times during 1919, up to 130 men, many of whom were returned servicemen, were fishing professionally in 8 miles of open water in the Swan*. Compared with present levels of fishing effort, this was extremely high and predictably resulted in uneconomic returns for many fishermen, forcing a number of fishermen out of the industry. The most popular species at that time were sea mullet, crabs and prawns (Table 2).

There are virtually no statistics available for the period 1922-1937. In an attempt to alleviate shortages in food supply during World War II, the canning of many species of fish commenced. Perth herring was one species which was very much in demand for this purpose. This is reflected in the increase in the level of production of this species from 1942 onwards. Sea mullet, cobbler, garfish, and blue sprats were also important canning species. Intensive canning of estuarine species continued for eight years. It continued to be practiced during the 1950's, but indications were that it was at a relatively low level of production. During the 1950's the fishery was maintained at a reasonably low level of effort. It increased somewhat in the late 1950's/early 1960's and has been maintained at that level up until the present day.

Since the last significant increase in effort in the early 1960's, there has been a noticeable increase in the level of production of Perth herring, cobbler and whitebait.

Perth herring production increased in response to the demand for this species as rock lobster bait. This increase corresponds well with the increased level of effort in the rock lobster fishery during the early 1960's (Morgan and Barker, 1974). Cobbler production increased sharply in 1959 and has continued to be maintained at that relatively high level. This increase reflects a sustained increase in the demand for this species as a favoured food species. Whitebait, which was never really fished commercially in the early years of the fishery, has gained tremendous popularity in recent years as an angling bait, and very recently as a gourmet food item in the Perth restaurant trade.

There has always been a demand for the remaining more important species taken from the estuary. Therefore with the exception perhaps of the two mullet species which have recently been used as rock lobster bait, changes in production probably reflect either the variations in spawning success of breeding populations outside the estuary, recruitment into the estuaries,

* Department of Fisheries and Wildlife file No. 32/19.

or the degree of suitability of the estuarine habitat for the growth and survival of the different species.

3. THE RECREATIONAL FISHERY

The recreational fishery is composed of two components, the unlicensed amateur line and crab fishery and the licensed amateur net fishery for fish and prawns. Old documents such as Fisheries and Wildlife Department files and the year book of 1829-1929, make reference to the fact that domestic fishermen, both anglers and netters were very active in the Swan-Canning estuary as early as 1912.

Throughout the whole of this twentieth century, there have been no formal surveys undertaken in the Swan-Canning estuary to determine the relative magnitudes of fishing pressure generated by each component, or their relative contributions to the total annual recreational catch from the estuary. However on the basis of results from some recent surveys of amateur fishing in other areas of the State (Lenanton and Caputi, 1975; Lenanton and Hall, 1976; Caputi and Lenanton, 1977), it is likely that the unlicensed component is the major contributor to the total annual recreational catch from the Swan-Canning estuary.

Recently, some observations at 70 popular locations around the estuary revealed that in excess of 1 000 persons fished at these locations on a typical weekend; and that an average evening catch (weekday and weekend included) was approximately 600 fish (Forbes and Fitzharding, 1977). There are no data available on the amateur crab catches from the estuary. However, it is certainly possible that quantities of crabs taken by amateurs would be similar to those quantities taken by the professionals.

The only data available on the daily fishing effort from the licensed amateur fishery are those collected by the Swan River Conservation Board during the summer of 1975/76 and 1976/77. The Board found that the number of people participating in prawning was only marginally less than the number reported to be angling. There are however some data available on the number of people who annually participated in the licensed amateur fishery (Table 3); the species they preferred to fish for (Table 4); and the number of units of gear they owned in order to fish for their preferred species (Table 5).

From these data it is clear that the participation in this licensed fishery is increasing each year, and that the majority of these people choose to fish for prawns, although there is significant and increasing participation in net fishing. Bearing in mind that the major contribution to the total recreational catch comes not from the licensed, but the unlicensed component, then both the total effort and catch of the recreational fishermen is likely to be substantial when compared to commercial production from the estuary. This was also thought to be the case early as 1919, when the recreational or domestic catch was thought to be equal to 50 to 60 percent of the professional catch (Fisheries and Wildlife Department file 19/19).

4. CONFLICTS IN USAGE

There is evidence available to show that conflict between professional fishermen and other users of the estuary has existed for many years.

In 1919, there were complaints from professionals that amateurs were killing many small fish, fishing in closed waters, and selling their catch more cheaply than professionals (F32/19* Fisheries - Closed waters - opening and closing of the water of the Swan River to net fishing 1912/41). There were also complaints that during the summer months of 1919, boating traffic and general recreational activities on the shallow banks had prevented professional fishermen from operating efficiently except in the hours from midnight to dawn (F32/19*).

Indeed, particularly in the summer months of years in the early twentieth century, the Swan River was used extensively for recreation, particularly pleasure boating of "an infinite variety" (Colebatch, 1929).

Illegal netting was also a problem during these early years as referred to in the 1912 annual report by the then District Inspector (F19/19*).

"The usual amount of illegal netting was carried on and much difficulty experienced by the inspectors. The professional poacher has become expert at the game. He no longer carries his net on the boat when going up the rivers - for that purpose he uses horse and cart and he carts his fish to the market from anywhere."

During that year 28 fishermen and one fish poacher were convicted of fishing illegally. There was also reference made in the 1829-1929 year book (Colebatch, 1929) to alleged depletion of fish in the Swan-Canning estuary:-

"At one time the river abounded in fish but with the growth of population along its banks and extensive netting, it now offers limited attractions to the angler."

So it is clear that the problems of today related to estuarine usage such as overfishing available stocks, conflict between various users of the estuary, in particular the amateur-professional conflict, and the problems of illegal fishing are not new, but have been in existence for many years. However, although it is easy to acknowledge that these problems have existed for many years, it is almost impossible to judge the relative severity of today's problems compared with those of the early years of the fishery.

The only quantitative information available on which judgements could be based is the historical production figures (Table 2); and perhaps all that can be said of production of these more important species is that the populations have been able to cope with both sustained professional effort which was high in the early years and somewhat lower in later years, as well as the substantial and presumably increasing effort generated by amateurs.

* F indicates Department of Fisheries and Wildlife file.

VI MANAGEMENT AND THE FUTURE OF THE FISHERY

From the foregoing sections of this paper it is clear that the bulk of the commercially and recreationally caught fish are mostly juvenile members of a large oceanic stock which utilise the Swan-Canning and other estuaries as nursery areas. Intense fishing in this estuary alone will probably not affect the overall level of stock abundance of these species, and will probably bear little relation to the number of fish that will be recruited into the estuary in the following years. Certainly the fishes of the Swan-Canning estuary have been able to successfully withstand over a century of exploitation, with periods of professional exploitation which have been more intense than the present day level. Therefore there is every reason to expect that fish populations which utilise the estuary will be able to survive similarly intense pressure in the future.

However, it is important to remember that many of these species similarly utilise other estuaries of temperate Western Australia. Thus intense pressure applied simultaneously to fish populations in <u>all</u> these estuaries may well pose serious problems to many fish stocks which utilise these estuaries.

A most important consideration in the question of the exploitation levels in an estuary such as the Swan-Canning is the control of the total level of effort to ensure that all commercial fishermen are able to gain an economic return, and all amateurs are able to have a reasonable share of the total catch of fish from the estuary, during any one fishing season.

In recent years amateurs complain that a decrease in their individual catch rates is an indication that stocks in the estuary are being overfished.

However, trends in the catch rates of professionals indicate that the abundance of estuarine stocks has not declined over recent years (Lenanton, unpublished), thus decreasing trends in amateur catches do not necessarily indicate that fewer fish are available, merely that more fishermen are competing for a share of a basically constant number of available fish.

A simplistic explanation of this situation is provided in Figure 6. The abundance in any one year of a species of fish that uses the estuary just for a nursery area has little influence on the abundance of that species on the estuary in subsequent years. Catches of this species will fluctuate from year to year depending on factors such as spawning and recruitment successes, larval mortality rates and the like; but mostly these fluctuations are round an average level of production which is reasonably constant from year to year. In contrast the total number of amateur fishermen electing to fish in the Swan-Canning estuary is increasing each year. Therefore each fisherman's share of the total catch would tend to decrease each year as the number of fishermen increased. In other words, a fishermen operating at a given level of effort at time A (Figure 6), would be expected to catch considerably more than a fisherman operating at the same level of effort at time B (Figure 6).

The other important aspect of management is to maximise the utilisation of this environment by potentially harvestable fish. This can be best achieved by ensuring that the estuary is maintained as an acceptable environment to fish which choose to utilise it. It is clear from earlier sections of this paper that man has very little control over natural phenomena which operate within the estuary. However, man is able to minimise the level of disturbance both to the important estuarine fish habitats, particularly shallow banks and foreshores and to adjacent areas such as water catchments and associated wetlands. This will help achieve maximum utilisation of this habitat by fish, which will in turn maximise the fish available for exploitation by both amateurs and professionals.

Finally juvenile fishes of the Swan-Canning estuary are derived from large oceanic populations which utilise a number of estuaries and limited areas of marine embayments along the coast of Western Australia.

Deterioration of one or all of these essential nursery habitats could result in a permanent break in the normal life cycle patterns of many of these species. The ultimate result of this could be a gross change in species composition; involving marked reductions,or in some cases the complete elimination,of species which once used to be common throughout our estuaries. Thus it is important that the criteria laid down for management of the Swan-Canning estuary be applied to the management of all temperate estuaries of the State, if our estuaries and fish population within them are to be enjoyed and utilised by future generations of Western Australians.

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TABLE 1. PRELIMINARY CHECK LIST OF FISHES OF THE SWAN-CANNING ESTUARY

FAMILY/SCIENTIFIC NAME	COMMON NAME	PREFERRED HABITAT				SOCIAL BEHAVIOUR		HUMAN EXPLOITATION		
		Pelagic	Demersal	Under 2m	Over 2m	Solitary	Schooling	Professional Fishing	Angling	Nil
<u>TELEOSTS</u>										
Mugilidae										
Aldrichetta forsteri	Yelloweye mullet		*	*			*	*	*	
Mugil cephalus	Sea mullet		*	*			*	*		
Sillaginidae										
Sillago punctata	King George Whiting		*	*	*		*	*	*	
Sillago schomburgkii	Western Sand Whiting		*	*			*	*	*	
Sillago bassensis	School Whiting		*	*	*		*	*	*	
Sillago maculata	Trumpeter Whiting		*	*	*		*	*	*	
Plotosidae										
Cnidoglanis macrocephalus	Cobbler		*	*	*	*		*	*	
Arripidae										
Arripis georgianus	Australian herring	*		*	*		*	*	*	
Arripis trutta esper	Australian salmon	*			*		*	*	*	
Exocoetidae										
Hyporamphus melanochir	Dusky sea garfish	*		*	*		*	*	*	
Hemiramphus regularis	Western river garfish	*		*	*		*		*	
Sparidae										
Acanthopagrus butcheri	Black bream		*	*	*	*		*	*	
Rhabdosargus sarba	Tarwhine (Silver bream)		*	*	*	*		*	*	

TABLE 1. (cont'd)

FAMILY/SCIENTIFIC NAME	COMMON NAME	PREFERRED HABITAT				SOCIAL BEHAVIOUR		HUMAN EXPLOITATION		
		Pelagic	Demersal	Under 2m	Over 2m	Solitary	Schooling	Professional Fishing	Angling	Nil
Platycephalidae										
Platycephalus endrachtensis	Flathead		*	*	*	*		*	*	
Carangidae										
Caranx georgianus	Trevally		*		*		*	*	*	
Trachurus mccullochi	Yellowtail Scad		*		*		*		*	
Bothidae										
Pseudorhombus jenynsii	Small toothed flounder		*	*	*	*		*	*	
Pomatomidae										
Pomatomus saltator	Tailor	*		*	*		*	*	*	
Engraulidae										
Engraulis australis fraseri	Southern anchovy	*		*	*		*	*		
Clupeidae										
Amblygaster postera	Scaly mackerel	*			*		*	*		
Sardinops neopilchardus	Pilchard (Mulie)	*			*		*	*		
Hyperlophus vittatus	Sandy sprat (Whitebait)	*		*	*		*	*		
Spratelloides robustus	Blue sprat (Blue sardine)	*		*	*		*	*		
Nematolosa vlaminghi	Perth herring		*	*			*	*		
Scombridae										
Scomber australasicus	Common or Slimy mackerel	*			*	*			*	
Tetraodontidae										
Torquigener pleurogramma	Banded toadfish (Blow fish)		*	*	*		*		*	

TABLE 1. (cont'd)

FAMILY/SCIENTIFIC NAME	COMMON NAME	PREFERRED HABITAT				SOCIAL BEHAVIOUR		HUMAN EXPLOITATION		
		Pelagic	Demersal	Under 2m	Over 2m	Solitary	Schooling	Professional Fishing	Angling	Nil
Gobiidae										
Amoya bifrenatus	Brindled goby		*	*		*				*
Favonigobius tamarenis	South-west goby		*	*		*				*
Favonigobius lateralis	Long finned goby		*	*		*				*
Pseudogobius olorum	Blue spot goby		*	*		*				*
Gerridae										
Gerres subfasciatus	Roach		*	*	*	*		*		
Apogonidae										
Apogon rueppellii	Gobbleguts		*	*	*	*				*
Atherindae										
Atherinosoma sp.	Hardy head	*		*			*			*
Teraponidae										
Pelates sexlineatus	Striped perch		*	*	*		*		*	
Amniataba caudavittatus	Yellowtail trumpeter		*	*	*		*	*	*	
Sciaenidae										
Argyrosomus hololepidotus	Mulloway		*	*	*	*	*	*	*	
<u>CRUSTACEA</u>										
Portunidae										
Portunus pelagicus	Blue manna crab		*	*	*	*		*	*	
Penaeidae										
Penaeus latisulcatus	King Prawn		*	*	*	*				
Metapeneas dalli	School Prawn		*	*	*	*		*	*	

TABLE 1. (cont'd)

Fishes of the following families are probably less commonly found in this estuarine system :-

Monocoontaidae (Leatherjackets)	Scorpidae (Sweep)
Kyphosidae (Drummers)	Nemipteridae (Butterfly breams)
Ostraciontidae (Box fishes)	Cheilodactylidae (Morwongs)
Cynoglossidae (Soles)	Blenidae (Blennies)
Clinidae (Weed fishes)	Callionymidae (Stink fishes)
Odacidae (Weedy whitings)	Pleuronectidae (Right-hand Flounders)
Enoplosidae (old wives)	
Diodontidae (Porcupine fishes)	Pegasidae (Dragon fishes)
Syngnathidae (Sea horses and Pipe fishes)	Triglidae (Gurnards)
Scorpaenidae (Scorpion fishes)	Gonorynchidae (Soul fish)
Elopidae (Giant herring)	Pempheridae (Pemferets)
	Ophlichthidae (Eels)

Sharks and rays likely to be caught include members of the families :-

Carcharhinidae (Whaler sharks) Rhinobatidae (Shovelnose rays)

Dasyatidae (Stingrays)

TABLE 2 - ALL AVAILABLE ANNUAL CATCH (KGS) AND EFFORT (MEN AND BOATS) DATA FOR MOST IMPORTANT COMMERCIAL FISH AND CRUSTACEAN SPECIES TAKEN FROM THE SWAN-CANNING ESTUARY (COMMERCIAL BLOCK 9501) OVER THE PERIOD 1912/1974

Species / Year	Perth herring	Mullet		Cobbler	Tailor	Whitebait	Flathead	Mulloway	Prawns	Crabs	Men	Boats
		Sea	Yelloweye									
1912	N.A.	118178	2077	496	6241	N.A.	698	361	*34680	† 6870	118	31
1913	← Data unavailable →											
1914	"	57382	12488	205	3727	"	283	1191	*25670	† 5950	44	22
1915	182	73386	7114	523	6954	"	795	273	*17785	† 4345	46	23
1916	← All fish 50182 →								*32010	†11895	40	20
1917	← All fish 105391 →								*33120	†16800	48	24
1918	42	110205	2250	966	9093	"	830	4902	*62250	†22035	73	33
1919	← Data unavailable →											
1920	N.A.	33177	2632	116	3704	"	800	1367	*17610	†10695	33	18
1921	"	†126072	†43762	†970	†15541	"	†856	2606	*25955	†14145	N.A	N.A.
	Data from 1922 - 1937 unavailable at this stage											
1938	"	← Data unavailable →							*10665	†23555	N.A.	N.A.
1939	324	5882	138	N.A	3471	N.A.	909	N.A	* 3995	†20955	63	32
1940	151	1564	322	"	1247	"	155	"	* 180	†26145	61	31
1941	14500	30651	5692	19662	4895	"	1167	171	510	13605	19	15
1942	79704	12286	1157	19316	2308	"	1019	172	93	11951	30	20
1943	67783	9972	1515	7594	5945	"	884	968	0	3127	20	7
1944	60431	5316	2207	2801	8837	"	784	506	0	3958	N.A.	N.A.
1945	50048	10484	7605	11788	6414	"	5494	679	76	23914	"	"
1946	24630	10101	4034	3143	7045	"	1332	1861	1996	7370	"	"
1947	9205	19059	3133	305	8390	"	991	982	3610	5335	31	19
1948	N.A.	24335	4734	1543	7616	"	420	306	11150	14838	N.A.	N.A.
1949	13600	18513	1119	769	6377	"	159	77	2209	16659	25	N.A.
1950	6375	24257	2532	1305	5849	"	379	155	1203	22525	N.A.	N.A.
1951	537	38749	2599	5592	5405	"	1007	99	2719	18014	"	"
1952	419	20761	1659	1485	4218	"	618	38	143	9675	16	13
1953	166	19777	2721	1957	2128	"	990	27	86	16781	18	15
1954	0	19519	2588	1284	1901	"	410	43	12	6973	13	12
1955	1871	15386	4631	3861	1710	"	1726	8	3	7588	14	13
1956	4278	20654	1965	1056	2624	"	3012	72	5076	8233	15	14
1957	19239	36500	4238	3183	2800	324	1350	67	8854	3899	17	15
1958	9192	86276	4987	5661	3496	N.A.	956	5	3856	11414	20	19
1959	8422	73883	5657	21523	3195	"	624	417	16369	10196	24	22
1960	15946	42941	20801	56586	4552	"	3869	639	7909	51203	30	27
1961	16153	116084	15157	44780	7977	"	2063	188	1014	10436	34	30
1962	11256	42390	10051	49371	2584	"	2097	557	1134	8714	23	20
1963	60361	64784	16268	38259	2464	823	4707	3667	607	1734	29	25
1964	65266	17899		23877	2769	2090	2150	638	2599	682	22	19
1965	43434	62761	3624	26098	1857	5833	1157	8452	2304	1745	27	22
1966	52340	74051	6106	13475	1551	4113	2133	2113	2295	1204	25	22
1967	89701	57241	8909	18345	1552	8257	3652	1908	785	8799	29	24
1968	177611	36558	5587	15142	1871	5389	3140	5369	270	15424	31	25
1969	62048	52387	17155	29127	2626	7266	2015	3587	748	7052	34	27
1970	46518	69267	29354	49554	2904	4944	3076	3477	1289	3324	30	25
1971	71454	44941	29406	39738	2330	1588	1996	3884	955	12737	33	27
1972	147432	48044	11241	23596	1684	3470	1017	1461	545	16179	33	27
1973	158606	76162	21045	33480	1899	12701	904	2630	150	12898	33	27
1974	97363	71627	15799	40210	823	5215	1955	2240	78	22700	33	28
1975	137983	54097	18995	31354	2178	16058	4326	29815	3168	21249	31	26

* Converted from gallons to Kg 1 gallon = 3.5 Kg

† Converted from dozens to Kg
- Crabs 1 dozen = 2.7 Kg
- Tailor 1 dozen = 1.4 Kg
- Sea Mullet 1 dozen = 3.0 Kg
- Yelloweye mullet 1 dozen = 2.4 Kg
- Cobbler 1 dozen = 6.3 Kg
- Perth Herring 1 dozen = 0.6 Kg

N.A. Not available.

TABLE 3 – The estimated number of Amateur Fisherman's Licenses issued from Perth and Fremantle District Offices over the period 1971/72 to 1975/76.

YEAR	NUMBER OF LICENSES ISSUED		
	PERTH	FREMANTLE	TOTAL
1971/72	4 118	1 506	5 624
1972/73	4 487	1 580	6 067
1973/74	5 264	1 905	7 169
1974/75	6 157	2 214	8 371
1975/76	8 680	3 268	11 948

TABLE 4 – The percentage of licenses issued at Perth and Fremantle Licensing Districts with fish and prawns recorded as a first and/or only preferred species*.

LICENSING DISTRICT	1973/74		1974/75		1975/76	
	PRAWNS	FISH	PRAWNS	FISH	PRAWNS	FISH
Perth	60	18	51	21	62	16
Fremantle	56	25	41	31	54	23

* Rock lobster made up the balance of the preferred species.

TABLE 5 - The number of prawn and fish nets owned by amateur fishermen who purchased licenses at Perth and Fremantle District Offices.

YEAR	NUMBER OF PRAWN NETS			NUMBER OF FISH NETS		
	PERTH	FREMANTLE	TOTAL	PERTH	FREMANTLE	TOTAL
1973/74	3 037	1 243	4 280	1 703	755	2 458
1974/75	3 313	1 252	4 565	2 512	1 074	3 586
1975/76	6 024	2 118	8 142	3 879	1 418	5 297

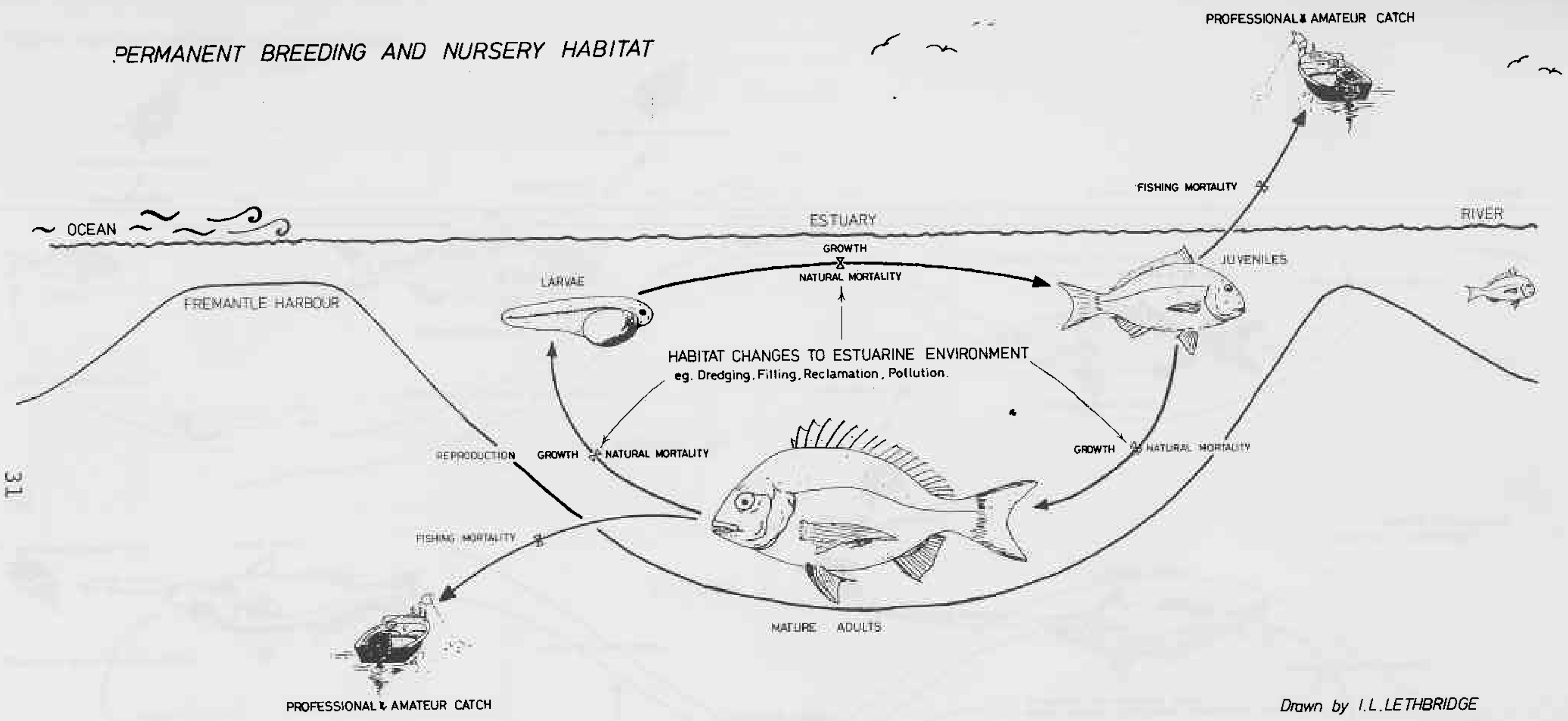

PERMANENT BREEDING AND NURSERY HABITAT
OCEAN
ESTUARY
RIVER
FREMANTLE HARBOUR
LARVAE
JUVENILES
MATURE ADULTS
GROWTH
NATURAL MORTALITY
HABITAT CHANGES TO ESTUARINE ENVIRONMENT
eg. Dredging, Filling, Reclamation, Pollution.
REPRODUCTION
GROWTH
NATURAL MORTALITY
GROWTH
NATURAL MORTALITY
FISHING MORTALITY
FISHING MORTALITY
PROFESSIONAL & AMATEUR CATCH
PROFESSIONAL & AMATEUR CATCH
Drawn by I.L.LETHBRIDGE

Figure 1.

NURSERY HABITAT FOR JUVENILES.

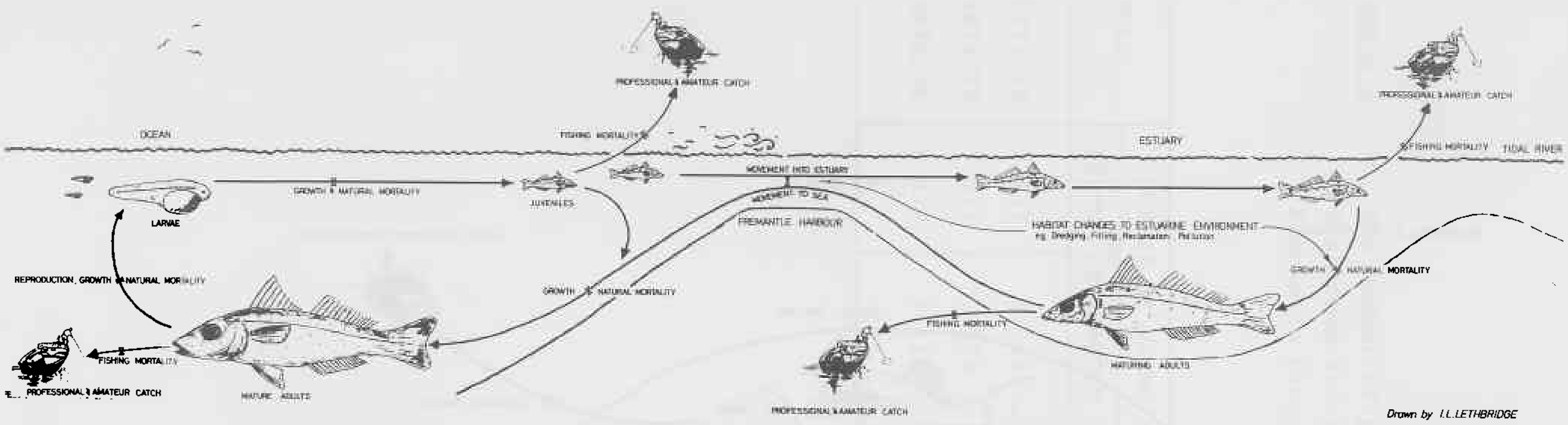


Figure 2.

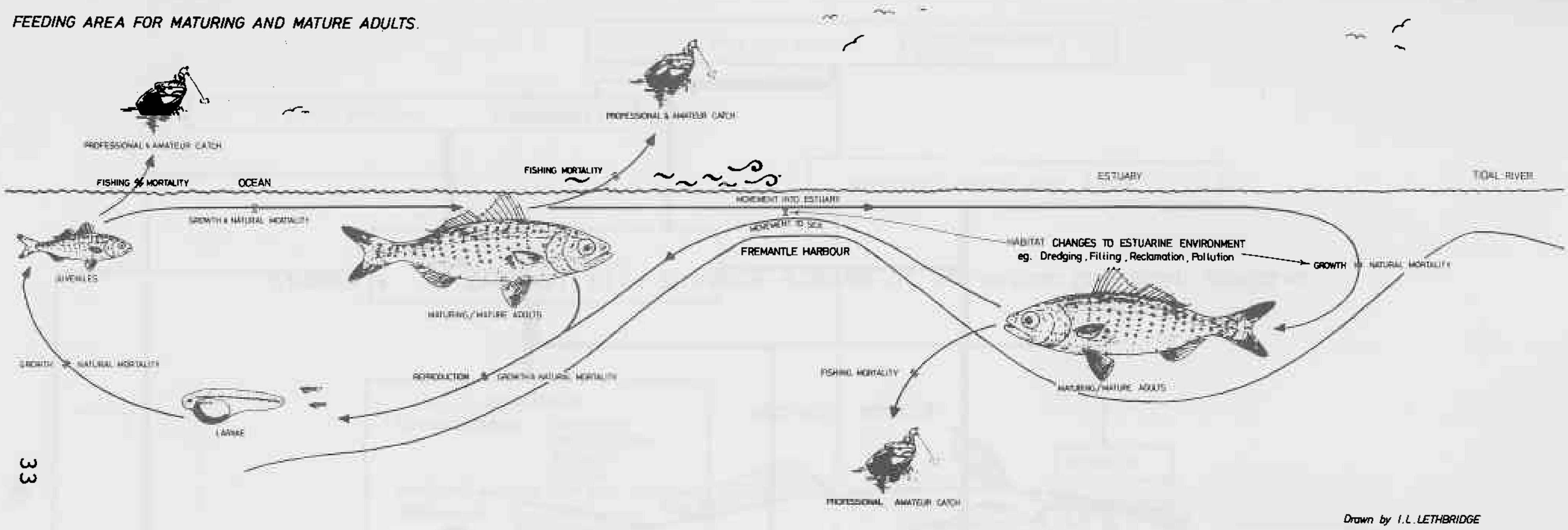

FEEDING AREA FOR MATURING AND MATURE ADULTS.
PROFESSIONAL & AMATEUR CATCH
FISHING MORTALITY
OCEAN
GROWTH & NATURAL MORTALITY
JUVENILES
MATURING/MATURE ADULTS
GROWTH NATURAL MORTALITY
LARVAE
REPRODUCTION
PROFESSIONAL & AMATEUR CATCH
FISHING MORTALITY
MOVEMENT INTO ESTUARY
MOVEMENT TO SEA
FREMANTLE HARBOUR
ESTUARY
TIDAL RIVER
HABITAT CHANGES TO ESTUARINE ENVIRONMENT
eg. Dredging, Filling, Reclamation, Pollution
GROWTH NATURAL MORTALITY
MATURING/MATURE ADULTS
FISHING MORTALITY
PROFESSIONAL AMATEUR CATCH
Drawn by I.L. LETHBRIDGE

Figure 3.

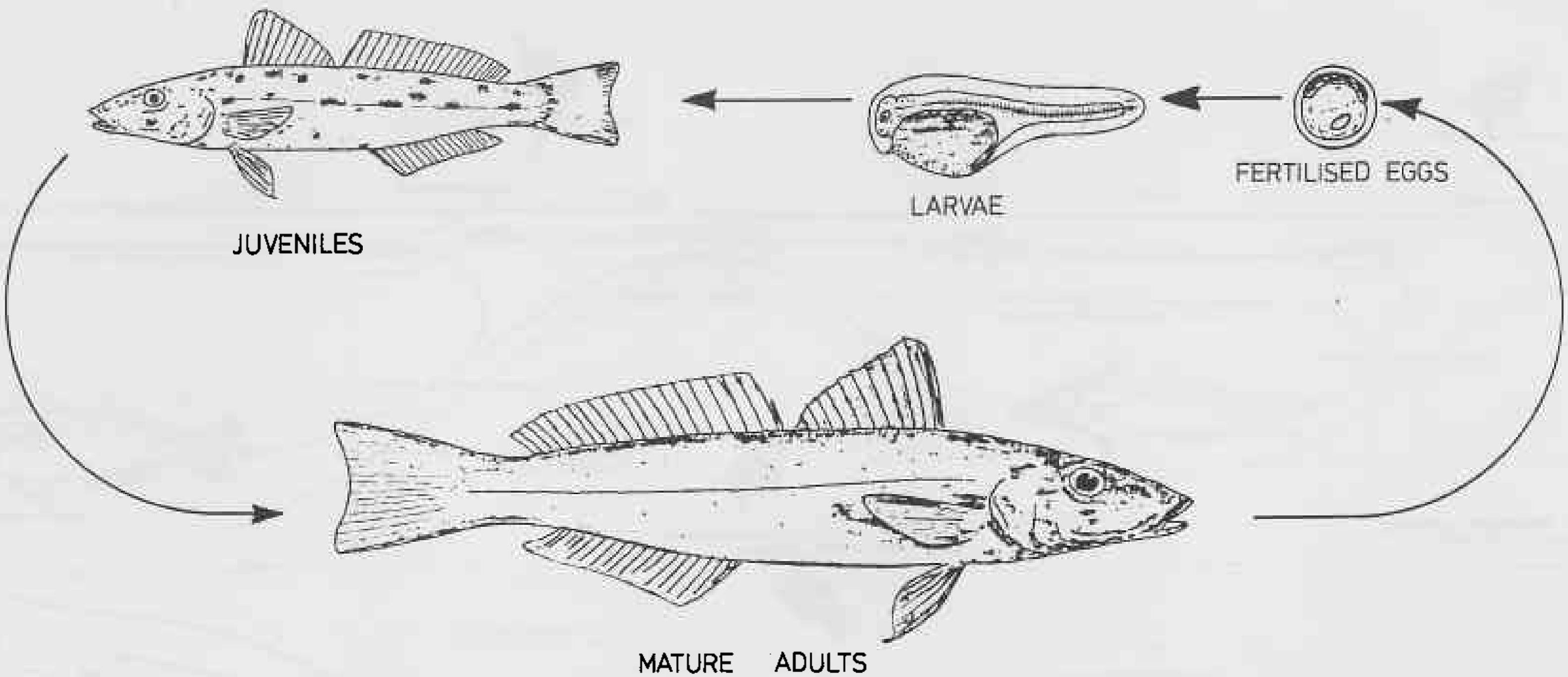
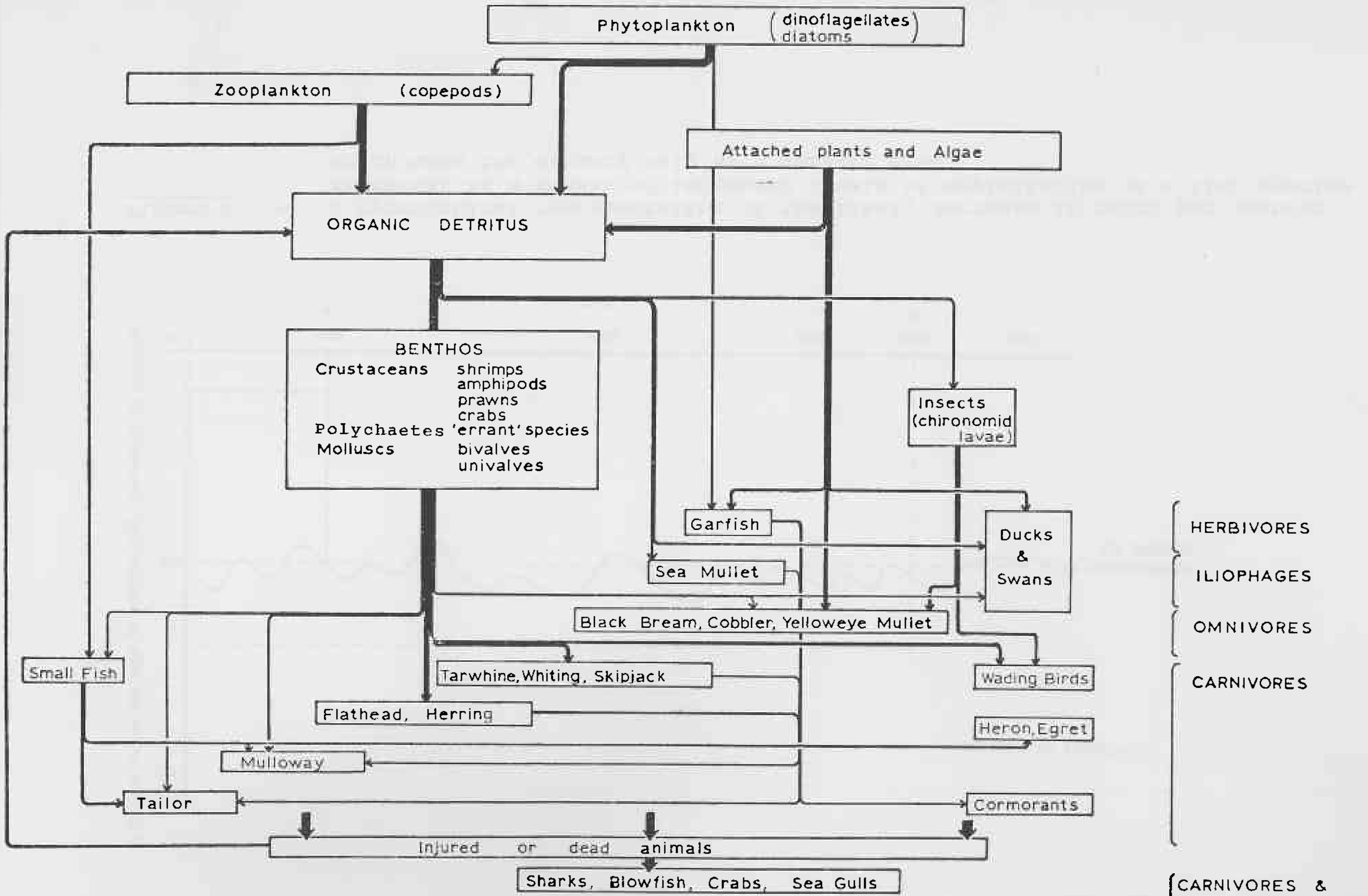
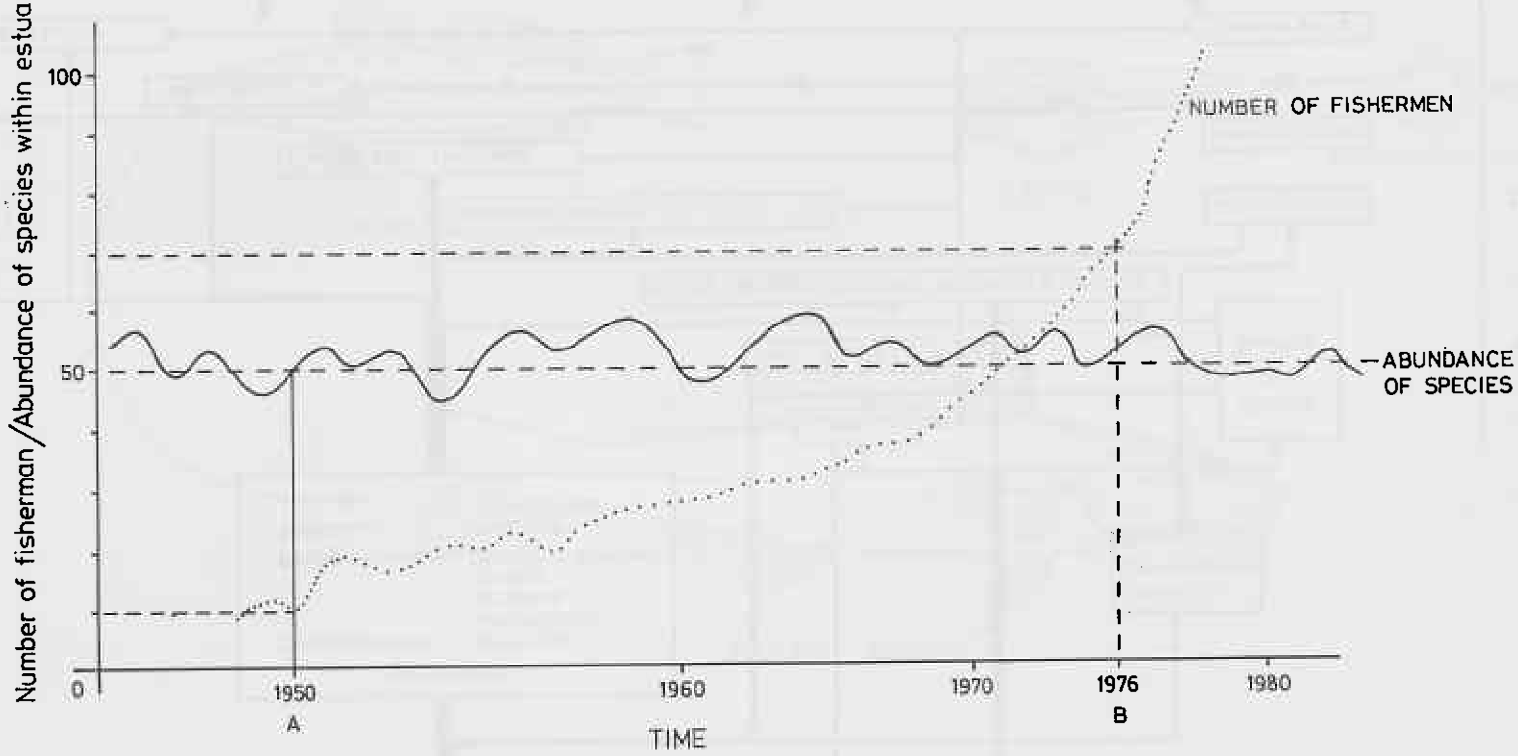


Figure 4 - Typical life history stages of an estuarine fish species.

Figure 5.- Simplified concept of the food chain in the South-Western Australian estuarine environment.





<u>Figure 6</u> - A hypothetical representation of the likely decrease in catch per amateur fisherman as a result of increased levels of exploitation of a fish species which uses the estuary only as a nursery area.

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