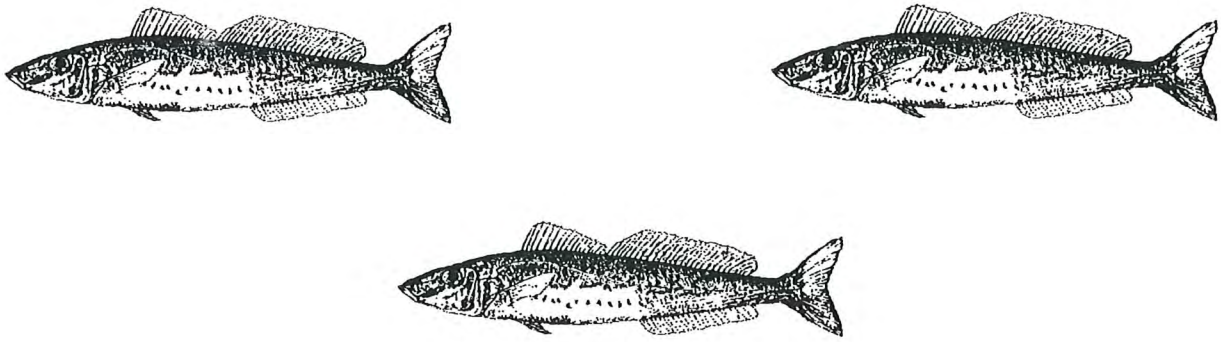
THE IMPACT OF COMMERCIAL HAULING NETS AND RECREATIONAL LINE FISHING ON THE SURVIVAL OF UNDERSIZE KING GEORGE WHITING
(Sillaginodes punctata)



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THE IMPACT OF COMMERCIAL HAULING NETS AND RECREATIONAL LINE FISHING ON THE SURVIVAL OF UNDERSIZE KING GEORGE WHITING (Sillaginodes punctata)

EXECUTIVE SUMMARY

1 INTRODUCTION

1.1 Rationale and Objective

Sea garfish (*Hyporhamphus melanochir*) is one of the species targeted upon over seagrass beds using lampara haul nets of mesh size 3 cm, and the inadvertent capture of undersize King George whiting is known to take place. Several recreational surveys of the King George whiting fishery in South Australia have also shown that undersize fish comprise at times, a significant proportion of all whiting taken by the recreational line fishing sector with some being retained and others returned to the water. The objective of the study is to determine the fishing impact of both commercial small mesh (3 cm) haulnet and recreational fishing on undersize KG whiting.

Stress and damage of undersize fish been recognised as serious problems which cause mortality in both recreational and commercial fisheries . From the overall review of literature it is clear that damage and stress impacted by fishing are the major cause of mortality. However, handling time, fish size, temperature (season) and fishing method are the deciding factors for the degree or the extent of mortality. They also point out that altering the gear selectivity without reducing damage or stress incurred during capture and escape may not be the most appropriate way of protecting undersize fish.

1.2 Method

The mortality of undersize fish can occur either during the fishing operation (Pre release mortality-PRRM) or after releasing the fish (post release mortality-PORM). Both types of mortality had been studied in the commercial haul net fishery and recreational line fishery. In order to understand the PRRM, monitoring of both sectors was undertaken throughout the year, to incorporate the seasonal fishing operations for each sector. PORM was estimated from the laboratory experiments carried out by transferring live undersize fish caught by both type of fishing. Stress analysis of fish was carried out by measuring the blood cortisol levels of undersize fish caught by both sectors. Field monitoring program had been undertaken with the cooperation of commercial haulnet fishers and recreational fishers (mainly through recreational clubs).

2 RESULTS

2.1 Impact of haul net

2.1.1 Catch and effort in haul net fishery

Garfish: During the year 1994, the commercial garfish net fishers expended 2402 boat days. Average catch per unit effort of garfish during the year 1994 was 91.7Kg per boatday. During season 1(January-March) the fishers applied 43% of their total effort resulting in average 74.6Kg per day. However, in season 2 (April-June) and 3 (July-October), the fishers applied comparatively much lower level of effort (27% and 23%) resulted in catches of 123.16Kg and 102.70Kg per boatday respectively. The extra effort applied by the fishers did not produce any surplus catch.

King George whiting: The legal size King George whiting by-catch was not proportional to the effort applied. On an average, for the year 1994, the haulnet fishers whilst targeting garfish caught 2.7Kg of King George whiting per boatday as by-catch. Season 2 and 3 accounted for a higher catch ratio of 3Kg and 3.7Kg per boatday respectively. In contrast, season 1 produced only 2.3Kg per boatday although a significantly higher effort was applied.

2.1.2 Undersize King George whiting caught in haul nets.

In 1994, it was estimated that a total of 23967 undersize fish KG whiting were caught in haul nets. The undersize fish caught in haul nets mainly depends on the selectivity, which is related to mesh size. The legal minimum mesh size allowed for haul nets is 3cm; however, our observations revealed that the fishers used mesh sizes varying from 2.6cm to 3.3 cm mesh. A typical 600m haulnet consisted of several panels of both old (15 years and more) as well as new net, which varied in ply size as well as mesh size. Another important aspect noticed was that frequently the material used for making the net varied from panel to panel. Therefore, a wider range of size groups were vulnerable to meshing in haul nets. The size group of 17 to 21 cm, which is most vulnerable to meshing in 3cm garfish net, dominated during the first season (January to March).

2.1.3 Mortality of undersize King George whiting

a. Pre release mortality (PRRM).

A total of 3357 undersize fish were estimated to be killed during haulnet operations, of which 70 % of the mortality was inflicted during the first three months of the year. Season 1 stands out with the highest percentage (51.6%) of undersize fish meshed in the nets. In season 1, a high mortality rate (24%) was observed compared with the other two seasons (8% & 3.5%). It was calculated that 2368 undersize fish were killed

during the first season. This was mainly due to the vulnerability of a high percentage of undersize fish in the size range of 17-21cm to small mesh haulnets during the first season.

b. Post release mortality (PORM)

The results of the experiments clearly indicate that the percentage of PORM was consistent in all seasons ranging from 10 to 12%. An average of 11% post release mortality was recorded from haulnet fishing. On an average, 30% of condition B (open wound) and 4% of condition A (scale damage or no visible injury) fish died. Therefore, the probability of survival rate could be as high as 95%, after considering the control mortality 1.1%, if the fish were released in condition A.

It was estimated that the post release mortality number was 2062 for haulnet fishing after subtracting the percentage of control mortality(1.1%). Based on the laboratory results of PORM and data obtained from field monitoring and fishers catch statics, a total mortality was estimated as 5419 (3357 PRRM + 2062 PORM) fish. It is important to mention here that the laboratory experiments may not give an accurate PORM rate because of the differences in conditions between the laboratory and at sea.

2.2 Impact of recreational line fishing

2.2.1 Undersize King George whiting number.

Preliminary estimates of the number of undersize fish caught in the recreational line fishery was provided by the recreational survey program currently being conducted by SARDI (FRDC project 93/249). As late as April 1995, the same project covered the Gulf St Vincent area. Studies on Spencer Gulf have just begun. Preliminary results of this survey estimated that in a total of about 180,000 (1994-95) undersize King George whiting were caught Gulf St Vincent. Based on the two months (April and May 1995) survey in Spencer Gulf, and considering the trend from the preliminary results of Gulf St Vincent, it is estimated that recreational fishers may have captured about 577,000 undersize fish.

2.2.2 Distribution and availability of undersize fish

Although season 2 produced 26.4 % of undersize fish, the results from the overall field observation clearly indicated that the recreational fishers had more probability of catching undersize fish at any given season than the haul net fishers. During seasons 1 and 3, the undersize and legal size catch ratio by recreational line fishers was almost 1:1.

The recreational catch size frequency distribution analysis did not reflect general abundance of fish as they had plenty of time and no restrictions on areas to

search for the fish where they were available. However, it was noticed that the recreational line sector caught a wide range of size groups starting from as small as 16cm to as large as 45cm. Among the undersize fish captured in different seasons, the size group mostly neighbouring the legal size (23 cm to 27cm) dominated the undersize catch.

2.2.3 Mortality of undersize fish

a. Pre release mortality (PRRM)

The pre-release mortality inflicted by recreational line fishers was found to be very low in comparison with the haulnet fishers. On an average, it was calculated that 1.7% of the total undersize fish caught by recreational line fishers died during the fishing process. About 77.7% fish caught during sampling were classified condition A, 16.5% condition B, 4.1% condition C and 1.7% mortalities. From this it can be noted that most of the hooking injuries were minor and did not appear to unduly effect the fish upon release. Based on the preliminary estimates of the total number of undersize fish caught by recreational line, the pre-release mortality was calculated at about 12491 fish.

b. Post release mortality (PORM)

The PORM experiment results clearly indicated that the survival rate of line caught fish was very high. The average PORM was about 1.3%. Based on the preliminary estimates of the total number of undersize fish caught by the recreational line fishery, the post release mortality was calculated at about 4031 (after subtracting the control mortality) fish.

3 KEY FACTORS INFLUENCING THE IMPACT OF HAUL NETS ON THE SURVIVAL OF UNDERSIZE KING GEORGE WHITING.

The survival/mortality rate of undersize King George whiting caught in haul nets and issues on fishing operation and gear are discussed in the following sections.

3.1 Haul net selectivity properties

Mesh size: The minimum length of garfish selected by the 3cm haulnet was 21cm. At the same time, the 3cm mesh captured undersize King George whiting down to 16cm. This was mainly because of the difference in morphological structure between the species. The quantity of this inadvertent undersize whiting capture and their survival rate will determine if there is any need to reconsider the existing mesh size.

Ply size: The usage of a wide range of ply size not only played a significant role in the meshing of fish but also the tangling and injuring of fish. It was observed that the lighter

ply sizes of 8 to 12 acted like a blade when fish were meshed or tangled and caused damage to the gills and skin. The ply sizes of 15 and over rarely caused meshing. However, the heavier ply size net not only costs more but also is likely to require more power for operating.

3.2 Fishing pattern and effort distribution

During the first three months fishers using small mesh hauling nets applied 43% of their total effort of the year; however, over this period the catch rates of garfish were not excessively high and the size group of King George whiting which was most vulnerable to the 3cm mesh was found to be relatively abundant. during this period. As a result, 41.1% of the total undersize fish was caught during these three months and 70.5% of total pre release mortality also occurred. This fishing pattern is questionable when compared to the availability of undersize King George whiting and their vulnerability to 3cm mesh at this time. There is a need to manage the high effort applied to garfish during January to March, without sacrificing catch. This would reduce the probability of catching undersize King George whiting and thereby increase the survival rate.

3.3 Fish handling time and procedure

Studies on other species, such as striped bass, indicated that lengthy handling periods could result in high mortality (Wydoski and Emery 1983). Dunning D J et al (1989) reported that immediate mortality decreased from 16.1% to 1.2% for striped bass captured in seines and from 17.7% to 1% for striped bass captured in trawls when the handling procedure was modified. Each power hauling shot took on average 2 hours to complete and during this time, fish are constantly being driven and chased.

3.4 Cause for undersize fish mortality

3.4.1 Netting injuries

Net related injuries are the prime factors which cause mortalities. Studies carried out by several authors have shown that physical damage incurred during capture could result in significant increases in mortalities. During the sampling, 27% of meshed fish died compared with a 7% mortality rate in pocket caught fish. Therefore, among the size group which are vulnerable to meshing in 3cm haul nets , just over a quarter of them were likely to die if captured. This was also supported by 83% of mortalities (PRRM) coming from the 17 to 22cm size group.

3.4.2 Stress

Various studies have shown that capture and confinement in fishing gears results in increased levels of stress. During the haulnet operation, the stress could occur from several factors such as severe exercise, over-crowding and confinement. The degree of

stress depends on the period during which the fish is subjected to an adverse situation. In other words, the handling time has a direct influence on the level of stress.

Statistical comparison of stress levels in both haulnet and recreational line caught fish indicated (Fig 19, 20 and table 6) that even though, the cortisol level in haulnet caught fish dropped significantly by 24 mark, after 48 hours the stress level was observed slightly higher than recreational line caught fish. This may be due to the difference in the type of stress the fish undergone during the capture. The reaction of a fish to a particular stress or will depend on the type of stressor, circumstances and severity.

3.5 Possible ways of improving the survival of undersize fish caught in haul nets.

It is clear from the present investigation and various studies conducted elsewhere that the netting damage and stress impacted by fishing are major causes for mortality. Therefore, altering the gear selectivity without reducing damage or stress incurred during capture may not be the most appropriate way of protecting undersize fish. Altering the mesh size/gear selectivity could be shifting the problem into another size group. This investigation could throw some light on the following important queries.

* Is the number of undersize King George whiting captured and killed by the haulnet significant enough to take a drastic policy change?

* Is there any room for improving haulnet fishing methods or fishing gear to reduce the number of undersize King George whiting caught?

Therefore, the total estimated mortality due to haulnet fishing during 1994 was calculated to be 5419. This mortality is not significant when compared to the overall size of the King George whiting fishery (which is equivalent to 690Kg compared with 640,000Kg commercial catch).

It may, however, be beneficial to attempt to reduce this mortality. Present investigations suggested two possible ways to improve the survival rate of undersize King George whiting. They are:

* to reduce netting related injury; and
* to reduce fish handling time.

The usage of heavier net ply size (15 and above) could reduce mortality by reducing the number of fish meshing and tangling and thereby reducing the severity of the injuries incurred. However, the economic and operational constraints due to heavier ply size would have to be considered.

A reduction in handling time could be achieved by adapting circular or semi circular haul net shots. However, this alteration would reduce the area covered per shot and whether this sacrifice in area would really make any significant difference in catch would need to be determined. It is essential for the fishers to understand that less handling time will increase the survival rate of undersize fish.

4 KEY FACTORS INFLUENCING THE IMPACT OF RECREATIONAL LINE FISHING ON THE SURVIVAL OF UNDERSIZE KING GEORGE WHITING.

The factors found to be influencing the overall mortality of King George whiting were:

5.1 Regular increase in fishing participation and effort

Due to the population growth and economic climate in South Australia, participation in recreational fishing has increased at a rapid rate. Although the mortality rate inflicted by the recreational section was found to be low, the larger numbers of recreational fishers increase the total mortality higher than in the haulnet fishery. Looking at the legislative review, historically the major controls used for managing the recreational fishing sector have been size and bag limits.

5.2 Rate of return of undersize fish

Although it appears that only a small percentage of recreational fishers retain the undersize fish that they have caught, a small percentage in a huge recreational sector can make a lot of difference. There is a greater need for compliance to isolate the genuine recreational fishers from the one who disregards the law.

5.3 Targeting undersize fish

There are areas where undersize King George whiting are found in abundance and recreational fishers fish these areas, knowingly or unknowingly. The ratio of undersize to legal size fish caught in these areas will be much higher than for areas where larger fish are predominant. These areas should be identified and fishing restricted or stopped when undersize fish predominant.

6 CONCLUSION

Damage and stress impacted by fishing were the major causes of mortality. Factors such as rate of fishing participation, fish handling time, gear characteristics and fishing operational procedure influenced the rate of mortality.

Although haulnet fishing inflicted a relatively high mortality rate, the total mortality was insignificant when expanded across the fishery, the major factors being low number of participants and a low proportion of KG whiting by-catch as the 3cm haulnet mainly

targeted garfish. The 3cm haulnet, when used to target garfish, contributed about 1% (6.5tonnes) of the total (664 tonnes) 1993-1994 commercial catch of King George whiting. On the contrary, the mortality rate inflicted by the recreational fishery was considerably lower than haulnet sector, but when expanded across a much larger number of participants, recreational line fishing accounted for greater number of mortalities than the commercial haulnet fishing.

7 RECOMMENDATIONS

8.1 A strategic plan should be developed to manage the use of 3cm net during the first three months of each calendar year in order to reduce the mortality of undersize fish without sacrificing significant commercial catches.

8.2 Better compliance with the haul net mesh size regulation must be promoted. A mesh size of less than 3cm should not be considered. An upper mesh size limit (say 3.1cm) would reduce the size group of King George whiting vulnerable to haul nets. Better compliance by the industry will improve the information available to the managers on the impact of nets on undersize fish.

8.3 In order to avoid meshing and tangling of undersize fish, a minimum ply size should be regulated. A study to determine the optimum ply size to avoid meshing and tangling and to understand the effect of ply size on the economics of fishing operations should be undertaken.

8.4 Fish handling time in the garfish haulnet fishery should be reduced. Furthermore, a study of haulnet fishing practises to improve the fishing methods without significantly effecting the economic viability of fishing should be undertaken.

8.5 A code of conduct on the sorting of catches should be determined. The return of undersize fish to the water should be a priority while removing the commercial catch from the net pocket. The duration in which the undersize fish remain confined in the pocket is one of the critical factors in determining the survival rate.

8.6 A study on the impact of 5cm net (gill/haul) and commercial line fish targeting King George whiting on the survival of undersize whiting should be undertaken. These sectors combined contribute more than 80% of the King George whiting commercial catch.

8.7 An education program highlighting to recreational line fishers that every undersize King George whiting they release has a maximum chance of survival should be implemented. However, it is recommended that the fishers should not deliberately catch undersize fish as even a small percentage of mortality inflicted

by a huge recreational fishing sector could make a considerable difference in total undersize fish mortality.

8.8 Consideration be given to restricting fishing in areas where undersize fish are predominant. These areas should be identified.

8.9 In order to facilitates better management of the King George whiting resource, regular monitoring of the recreational fishery in addition to the commercial sector is essential.

THE IMPACT OF COMMERCIAL HAULING NETS AND RECREATIONAL LINE FISHING ON THE SURVIVAL OF UNDERSIZE KING GEORGE WHITING *(Sillaginodes punctata)*

1 INTRODUCTION

1.1 Origin of fishing impact investigation in South Australia

Fishing impact investigation in South Australia originally resulted from the conflict of resource sharing between "netters" and "hookers". It can be traced back as early as September 1943 (Moorhouse, 1946), when the Corporation of Port Lincoln inquired if netting at local bays had any injurious effect on fishing. This query emanated after several local fishers were reported to have stated that previous netting at Proper Bay had so impaired the area that there had been a depletion of the fish in that area. During the same period, Mr. Moorhouse, the Chief Inspector, was promoting netting to diversify the marine scalefish fishery. A detail of historical perspective including changes in netting and line fishing is summarised in chapter 2.

Over the past decade the issue of resource sharing between recreational and commercial fishers has become the magnum opus of the fisheries management problem for the fisheries administration. The commercial industry has emphasised that the recreational fishers are the main impacters on the fish stock. On the other hand, the recreational sector has a strong conviction that the commercial fishing industry and their fishing practices are responsible for the depletion of valuable fish stock such as King George whiting. Studies indicate a poor status of the King George whiting stocks (SARDI, KG whiting workshop 1995).

This study was undertaken to assess the fishing impact of both commercial haulnet (3cm mesh) and recreational line fishing on undersize King George whiting and **does not cover the commercial line fishery or gill net fishery.**

1.2 Rationale

King George whiting (*Sillaginodes punctata*) is the highest valued marine scalefish species taken in inshore waters of South Australia by both commercial and recreational boat fishers. Around half of the annual commercial catch is taken by the netting sector (350 tonnes; $2.5 million) and the rest taken by handline fishers. In the hauling net fishery, in addition to King George whiting, a number of other species are targeted, depending on their relative abundance and value. Sea garfish (*Hyporhamphus melanochir*) is one of these species, and when targeted over seagrass beds using hauling nets (minimum 3cm mesh size), the inadvertent capture of undersize King George whiting is known to take place (Jones, 1982). Targeted netting for garfish comprises a significant proportion of the total hauling net effort (30% or 2,900 boat days in 1991/92).

Several recreational surveys of the King George whiting fishery in South Australia have also shown that undersize fish comprise at times, a significant proportion of all whiting

taken by the recreational line fishing sector (Jones, 1982, McGlennon & Evans, 1992). Some are being illegally retained and others are returned to the water.

Preliminary stock assessments have been carried out on King George whiting and garfish (Jones et al, 1989), Both are fully exploited and recommendations have been made to control fishing effort on both species (Govt. of SA,White Paper, Aug, 1992).

Because of the state of the fishery for both these species, there is a real need to determine the mortality rate of undersize King George whiting taken as a by-catch of the garfish net fishery and the recreational line fishery. These rates will be incorporated into the models developed by Sluczanowski et al, 1992; and Jones et al, 1989 for these species and future detailed model, to determine whether they significantly affect the spawning potential of these species. If they are found to be significant, recommendations on how to reduce the impact on undersize fish will be made to the Marine Scalefish Fishery managers.

These studies will also assist in the management of similar garfish and whiting fisheries in the bays and inlets of Victoria.

1.3 Objectives

The major objectives of the project are:

* to determine the impact of commercial hauling nets for garfish on the King George whiting fishery and

* to determine the impact of recreational line fishing on the mortality of undersize King George whiting.

1.4 Issues

The main issues considered for the project are:

* inadequate knowledge on the quantitative effect of commercial and recreational sectors up on the stock of King George whiting;

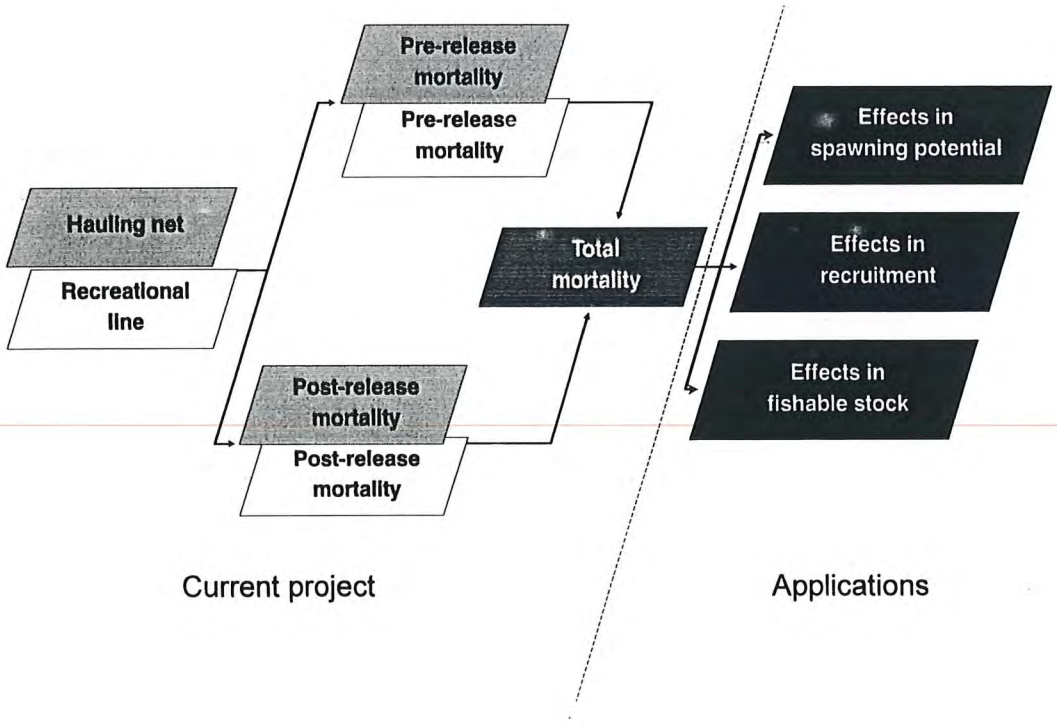
* interaction between commercial net and recreational line sectors on their respective catch rates;

* need for optimising the mesh size of haulnets while investigating the possibility to decrease the vulnerability of undersize King George whiting to haulnets and also the possibility of increasing the legal size of garfish;

* need to investigate recreational line fishing practices, in order to improve survival of undersize King George whiting and

* use of this information to determine the effect on the spawning potential and yield of King George whiting.

Fig 1 Project components and applications



2.HISTORICAL PERSPECTIVE OF NET AND LINE FISHING

Through examinig historically the legislation pertaining to the King George whiting fishery both in relation to hook and line and net fishing methods, one appreciates the metamorphosis undergone by the net and line fishery sectors over the last sixty years. It also provides a background to the basis for some common misconceptions held by competing participants in this fishery.

The proportion of undersize fish in a commercial or recreational catch depends on many factors including fishery regulatory measures and the influence of socioeconomic developments. The major points of consideration are:

* minimum legal size for this species;
* legal mesh size for the fishery;
* temporal and spatial fishing restrictions;
* level of fishing participation;
* development in fishing technology;
* overall status of the economy; and
* general fisheries policy.

Some of these changes over time in the King George whiting fishery and the impact some of these on the share of undersize fish captured and released during common fishing practises are discussed.

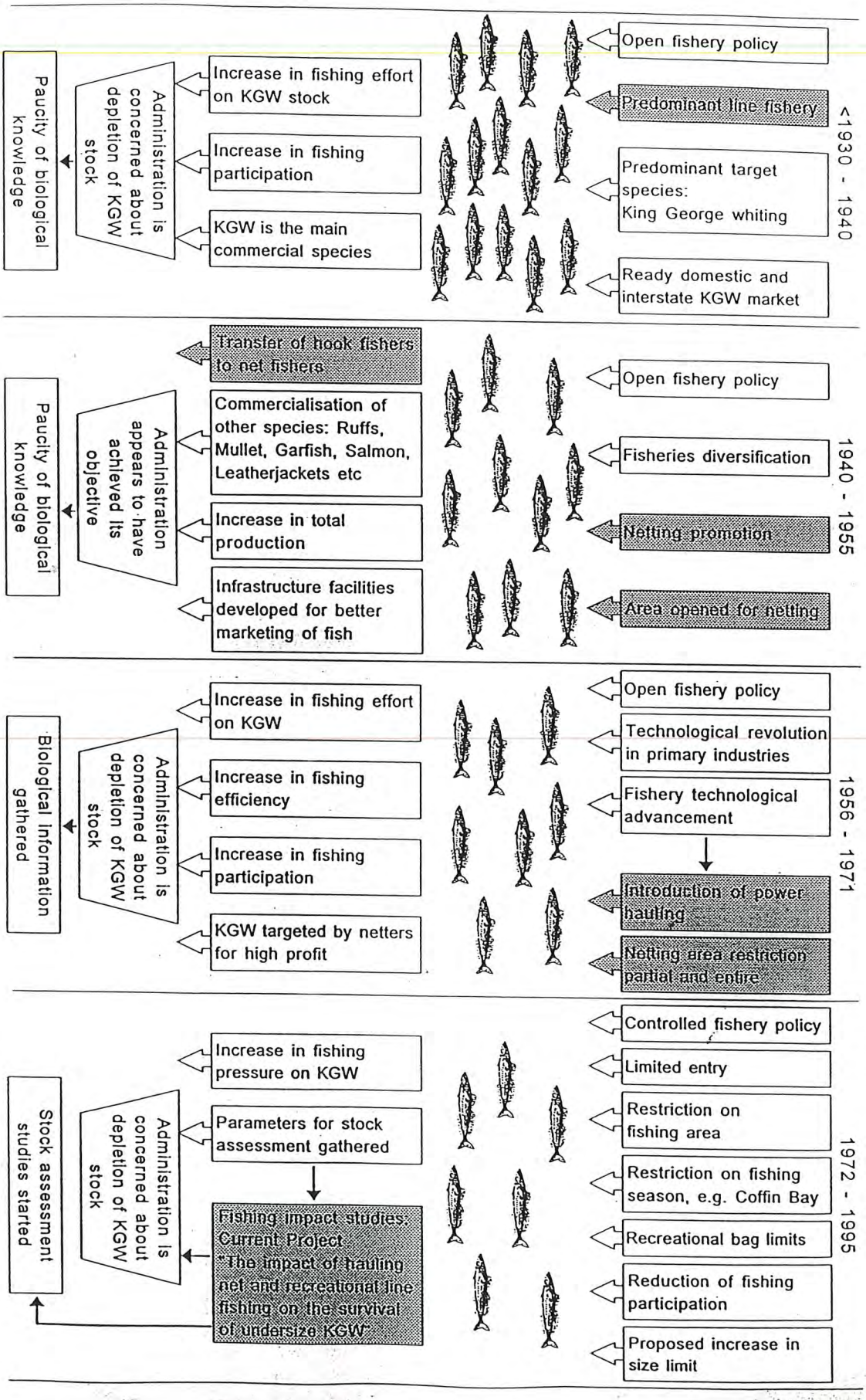
2.1 Early History

The Marine Scalefish Fishery commenced in South Australia in its current form shortly after European settlement. Various legislation was enacted culminating with the Fisheries Act (SA) 1917 which was revised and replaced by the Fisheries Act (SA) 1971. During the 1930's, the Marine Scalefish Fishery centred around line fishing and the predominant target species was King George whiting. The use of nets was not prevalent and the fishery was driven by the market at any given time. Fish caught by net fetched a comparatively lower price than line caught fish, as fish caught by line could be kept alive in 'wells' in the fishing boats. This allowed fish to 'purge', and without refrigeration, this improved the quality of the fish when they arrived at markets. Most line fishers could also hold their fish for longer periods of time whilst awaiting transport to markets. The King George whiting was in high demand mostly due to the following two factors.

* the flavour and quality of the flesh remained intact for a comparatively longer time than other fish species, and

* the fish had both domestic and interstate market acceptability.

Fig 2 Metamorphosis of net and line fishing and its impact on the King George whiting



Thus King George whiting was the principally targeted fish in the Marine Scalefish Fishery. The preferred method of capture was by hook and line. Over this period of time, effort expended by the fishers increased, and fisheries managers became concerned about the King George whiting stock.

2.2 Early regulations on fishable stock and gear

The minimum size limit and minimum mesh size regulation were some of the important management measures introduced during the early 1900's.

2.2.1 *Size Limit*

The size limit has not altered appreciably since the first size limit of a minimum weight of 5 ounces was introduced in 1888. This limit was later converted to 11 inches Total Length and in 1971 was converted again to 28 cm following the introduction of the metric system into Australia. Current research suggests a fish weighing 5 ounces would equate to a fish measuring 28 cm (Jones pers com). No information is available as to the basis used to set this size limit.

2.2.2 *Minimum mesh size*

The earliest records available show the minimum mesh size allowable for garfish seine nets was $1^1/_4$" (Fisheries Act (SA) 1917). This mesh size was altered with the introduction of the metric system to 3cm and this is currently the minimum allowable mesh size in the Marine Scalefish Fishery. This conversion from imperial to metric units may have had an impact on the capture of undersize King George whiting. The exact conversion for $1^1/_4$" is 3.175cm. This reduction in net size, although small, may be significant as it coincided with an increase of net effort at this time.

2.3 Diversification of Marine Scalefish Fishery

During early 1940's, the fisheries administration considered it necessary to reduce the fishing effort applied to King George whiting. A strategy of fisheries diversification was initiated by Mr. F. W. Moorhouse, Chief Inspector of Fisheries. The major objectives of this plan were:

* to reduce fishing effort on King George whiting;

* to diversify the fishing effort to other less commercially important fish species such as garfish, tommy ruffs, mullet and salmon; and

* to increase fisheries production and the subsequent revenue to the state.

Moorhouse planned to achieve this objective by promoting net fishing which would allow the Marine Scalefish Fishery to diversify into a multiple species fishery. The development of infrastructure facilities such as refrigeration and insulation technology during 1940's helped to preserve fish and allow the transport over longer distances those species which did not have the keeping qualities of King George whiting. This in turn helped to develop a diversified market whereby less familiar species like garfish, tommy ruffs, mullet, leatherjacket and Australian salmon would fetch reasonable prices. Overall the circumstances were conducive to develop a diversified fishery. The constrains Mr. Moorhouse faced were:

* promoting netting in general; and

* transferring hook fishers into netting.

Moorhouse, in his report (1946) to then Minister for Fisheries, wrote 'despite the fact there is heavy demand for fish of all species, many fishermen still do not realise how important our commoner fish are. Netting demonstrations were given at several ports but most men showed little interest, and even contended that netting in the shallow waters of their locality would ruin their hooking livelihood.' Reluctantly fishers started to adopt net fishing. However, this perception and fear of the impact of netting has continued amongst hook fishers since that time.

The objectives of the government at that time appear to have been achieved, that is. to reduce fishing effort applied to King George whiting and diversify the fishery by promoting netting. However, the dramatic changes of circumstances during the 1960's forced government to re-think their strategy.

2.4 Technological revolution

During 1960's a technological revolution occurred in all sectors of South Australian primary production, including fisheries, and especially in the area of harvesting and post-harvest technology in agriculture. Machines started replacing human and did the same job a lot faster and more efficiently . The agricultural sector, which employed a significant portion of the rural population, no longer needed the same levels of personnel (bulk handling of grains and mechanisation). A percentage of this surplus agricultural labour force naturally looked to other forms of primary production, such as fishing, to replace their loss in income (Cleland 1980). At the same time, the technological advancement in fishing gear and boats (monofilament nets, high power and affordable petrol motors, planning hulls constructed of plywood) significantly increased fishing efficiency. Major improvements were also made in preservation and transportation of fish. These developments brought results which were of major concern to fisheries administrators:

* an increase in the number of participants, especially in the inshore fisheries in both Gulfs and West Coast Bays;

* an increased in total fishing effort; and

* an increase in the catch per unit effort as the efficiency of fishing operations improved.

This adversely affected the King George whiting stock. The netting promotion and the diversification strategy no longer worked under the circumstances. The administrators were experiencing the same concern that had been felt twenty years before. This prompted the need for new management strategies and the requirements for legislation to introduce these changes for the longer term benefit of the fishery.

2.5 Introduction of Controlled Fisheries

2.5.1 *Limited entry fishery*

The principal strategy adopted was to limit the number of participants in the fishery. Previously anyone wishing to enter the fishery could purchase a commercial fishing licence . The legislation introduced in 1970 restricted the issue of commercial fishing licences to persons who could prove they had previously operated as commercial fishers. Licences were further classified into class 'A' and class 'B'. Class A licences were issued to fishers who were solely dependant on fishing for their income and a B class licence was issued to those fishers who had other 'part-time' employment.

2.5.2 *Further Rationalisation of the Commercial Fishery*

In 1979 the issue of Marine Scalefish Fishery licences was further restricted by commercial licences not being re-issued if a minimum level of fishing had not been met during the previous year and principle of owner, operator was applied to this fishery. In 1980 further restrictions were introduced to limit the maximum length of nets to 600m and class 'B' fishers were advised they would no longer be entitled to use nets. In 1990, a discusion paper (Jones et al, 1989) by the South Australian Government. A supplimentary discussion paper (Rohan et al, 1991) released in July 1991. These papers reviewed the status of the Marine Scalefish Fishery and resulted in the introduction of further measures to reduce the number of Marine Scalefish Fishery licences.

2.5.3 *Recreational Fishery*

This fishery has been managed traditionally by the use of size and bag limits. Recreational fishers have also been able to use nets, with varying restrictions, but the principle capture method for King George whiting has always been by hook and line. The size limit of 28cm applies to both commercial and recreational fishers.

Bag limits were first introduced for recreational fishers in the Coffin Bay and Port Broughton areas. These regional bag limits were replaced by a state wide bag limit of

30 fish per person per day in 1971. This bag limit was reduced to 20 fish per person per day and a boat limit of 30 fish when 3 or more persons were on board a boat in 1994.

2.5.4 *Proposed Future Arrangements*

Following a review of the net fishery, the Minister for Fisheries announced in May 1995 the following:

* participants in the Marine Scalefish Fishery would be reduced in number by two thirds over the next two years,

* permanent netting closures would be extended and include Franklin Harbour, northern Spencer Gulf, Port Lincoln bays, Coffin Bay and Encounter Bay,

* nets would be prohibited near all town jetties and beaches,

* week-end and holiday closures for net fishing would apply,

* recreational nets would be prohibited,

* the size limit for King George whiting would be increased from 28cm to 30cm and then to 32cm by 1 July 1998;and

* when using fish nets, it would be required that the fish must be sorted before the net is removed from the water.

2.6 The effect of regulations and events in other Fisheries on King George whiting fishery.

Any additional fishing pressure/participation not only impact on legal size fish but also proportionately impact on undersize fish. The effectiveness of legislative changes on the King George whiting stock have been difficult to assess, however other fisheries activities can be shown to have been counter productive to these measures. An increase in recreational fishing and declining stocks of other species such as snapper and sand crabs have led to effort previously expended on these species being directed to King George whiting. No studies have been undertaken to provide evidence related to this extra pressure on King George whiting. However, available information indicates that the marine scalefish fishers who were targeting sand crabs in Coffin Bay prior to the collapse of this fishery in 1993, opted to target King George whiting in Coffin Bay in 1994. This was derived from commercial fisheries-dependent information in the assessment of the biological status of the King George whiting fishery (Jones, 1995 Unpublished.). Jones and Luscombe (1993) also suggest that with the decline in targeted hand-lining fisher days for snapper, the fishers now have the opportunity to spend a greater proportion of time targeting other species such as King George whiting.

2.7 Discussion

2.7.1 *Biological Knowledge*

Looking at the history of the fishery over sixty years, our biological understanding of the King George whiting stock has remained minimal, although it should be acknowledged that significant research information is now becoming available. This knowledge clearly indicates that the level of information on King George whiting is not adequate to undertake a complete stock assessment (SARDI, KG whiting workshop 1995). The legislative decisions based on biological factors were mainly derived from the necessarily conservative advice of scientists because a full assessment of the King George whiting stock has not been undertaken. The results of the present investigation should incorporate into developing a stock assessment model.

2.7.2 *Legislation*

Reviewing closely the legislation and the impact on the King George whiting fishery, the main problem in this fishery is over-exploitation. This issue remains unsolved and may have worsened despite the legislative changes introduced since the mid 1930's. Administrators of the 1990's, as of those of the 1930's experienced and still are experiencing similar constraints and problems. In the 1930's, the administrators were trying to diversify the Marine Scalefish Fishery, to reduce fishing pressure on King George whiting, through promoting netting and opening additional areas to netting. In comparison, in the late 1940's, administrators began to introduce area closures and restrict netting in many locations across South Australia. During the late 1960's and early 1970's, the administrators introduced restrictions on the numbers of fishers participating in the fishery and since then have attempted to restrict effort, mainly by reductions in the number of commercial fishers and the number of nets endorsed in this fishery.

2.7.3 *Fishing Technology and its Impact on Fishery*

Technological advances over the years have had a tremendous impact on natural resources including fisheries. In fact technology has gone so far as threaten the sustainability of some fishery resources. Technological advances in other sectors (agriculture) also affected fisheries, yet studies or investigations on the impact of various technology on fish stocks has received little attention. It is important to note that it is equally essential to study this impact, along with biological research on the stock, stock status and structure and how, and at what rate, we are removing the stock. It is also important to determine, while a certain amount or level of stock is being removed, how much the fishery is impacting on the remaining stock.

2.7.4 *The Present Project and it's Importance in Management of the Fishery*

This investigation to quantify the level of incidental exploitation and it's relative impact on a resource (the King George whiting stock) by both commercial and recreation sectors is the first of its kind in Australia. Many developed countries have carried out studies on this aspect as a priority, as the results give the manager an opportunity to look in more detail at the impact of management decisions on the stock. This study focuses on what happens to future stock (undersize fish) every time fishers remove a certain quantity of fishable stock. Traditionally researchers have closely examined the harvest and biology of the species (in this case King George whiting) which is explicit. What we have failed to understand is that while we harvest the stock, we are impacting the remaining stock. This project investigates the impact of hauling net and recreational line fishing on the under size King George whiting. "Today's undersize is tomorrow's legal size". Both explicit and implicit impacts in terms of mortality are important parameters for the stock assessment of any fishery.

3. REVIEW OF THE PREVIOUS RESEARCH CARRIED OUT ON THE IMPACT OF HAUL AND MESH NET AND LINE FISHING

Stress and damage of undersize fish have been recognised as factors causing fish mortality in both recreational and commercial fisheries. Several studies (reviewed in this chapter) on different fisheries indicated that the mortality rate varies significantly according to:

* gear type;
* species type;
* size of fish; and
* temperature-environmental conditions.

Although research has been conducted on most fishing gear this review considers hauling and mesh nets and line fishing.

Recently a review by Chopin and Arimoto (1995) identified the range of injuries, stress reactions and mortalities that can occur during capture and escape for the main types of fishing gear used for harvesting both marine and fresh water fish. They concluded that immediate and delayed mortalities can occur in fish escaping from fishing gear, but the high variation in mortality rates within experiments is associated with a lack of information on how condition of the fish is affected by various fishing stressors and the type and severity of physical damage received. They also point out that altering the gear selectivity without reducing damage or stress incurred during capture and escape may not be the most appropriate way of protecting undersize fish.

3.1 Studies on the impact of netting.

A number of factors impacted by netting are known to cause mortality in undersize fish. These include:

3.1.1 *Catch rate*

Fritz and Johnson (1987) reported that catch size and oxygen concentration affected survival of commercially seined fresh water drum, *Apliodinotus grunnient,* intended for release back to Lake Erie or live transport to fishing ponds. Survival was inversely related to the time that fish in beach seines were exposed to deoxygenated water and, in general, survival was greater in smaller catches than larger catches. Maintenance of oxygen levels in the seine net, by encouraging water flow into the beach seine, direct delivery of oxygen, or less crowding of captured fish were proposed to improve the survival of released fish.

3.1.2 *Physical injuries and mortality*

During the process of commercial net fishing, undersize fish are subjected to the capture stress and physical injuries due to contact with other fish, debris in the net, or the actual fishing gear. Several authors (Stringer, 1967; Hislop and Hemmings,1971; Thompson and Hunter, 1973; Warner, 1979; Smith and Howell, 1987; Wertheimer, 1988; Stevens, 1990; Sangster and Lehmann, 1993) have shown that physical damage incurred during capture can result in significant mortalities of fish.

3.1.3 *Handling time, size of fish and catch rate*

In the case of beach seine nets, Neilson et al. (1989) found that handling time, total catch and fish length influenced the halibut survival. Dunning et al. (1989) achieved a significant reduction in mortality rate by modifying the handling procedure (the trawl cod end was unloaded in the water rather than lifted onto the deck) in fishing for striped bass with seine and trawl nets.

3.1.4 *Mesh sizes*

Estimation of the relative percentage of undersize fish caught by the different mesh sizes has been carried out by Ehrhardt and Die (1988). This is to improve the yield per recruit which is always obtained by influencing mesh size, gill-net fishing mortality, or both. Mortality caused by pelagic gillnetting is estimated to be equal to the catch for salmon in their penultimate year of life, and equal to about a quarter of the catch for salmon in their final year of life (Ricker 1976).

Ishida et al. (1969) used an underwater television camera to observe losses from gillnets, and found an average of 16% loss in 4 trials. Losses were greater from the smaller of the two mesh sizes used (Table 1).

Table 1 Mortalities from seine and gil nets.

Fishing Gear	Species	Mortality(%)	Comments	References
Purse seine	Scomber Sp.	50-90	Simulated purse seine experiment	Lockwood et al. (1983)
Danish seine	Cod.haddock	0<10	Fish retrieved at surface	Soldal & Isaksen (1993)
Beach seine	Striped bass	1-17	Mortalities of released fish reduced through improved handling techniques.	Dunning et al. (1989)
Beach seine	Fresh-water drum	84.7	Estimated mortality after release due to stress and injury.	Fritz & Johnson (1987)
Beach seine	Striped bass	17.7-1.0 16.1-1.2	Improved handling methods used to reduce mortality.	Fritz & Johnson (1987)
Gillnets and entangling nets	Pacific salmon	80-100	Cumulative mortality in captive fish.	Thompson et al. (1971)
Gillnets and entangling nets	Pacific salmon	80	Cumulative mortality due to scale damage and stress.	Thompson & Hunter (1973)
Gillnets and entangling nets	Herring	1.9	Actual mortality was very high but attributed to disease.	Hay et al. (1986)

3.2 Studies on the impact of line fishing

3.2.1 *Baits and lures*

Clapp and Clark (1989) compared the hooking mortality of smallmouth bass (*Micropterus dolomieui)* caught on live minnows with those on artificial spinners. They found that mortality was 11% for fish hooked on minnows and 0% for those hooked on spinners. The study suggested that it may be necessary to restrict fishing gear to artificial lures to ensure the success of no-kill fishing regulations for smallmouth bass. Similar studies conducted by Nuhfer and Alexander (1992) supported the results; however, certain types of lures were more likely to be engulfed deeply, particularly by larger fish and thus were more likely to cause death. Lures that exhibit vigorous wobbling action when retrieved appear less likely to be deeply engulfed and consequently cause less mortality. Similar results were reported by Payer et al., 1989 in walleyes *(Stizostedion vitreum)* caught on artificial and live baits.

3.2.2 *Hooking position, injury and mortality*

Working in the Strait of Georgia, Milne and Ball (1956) observed 100 % mortality of Pacific salmon (*Oncorhynchus sp*) hooked in the gills. About 50% mortality has been noted of those hooked in the eye and 22% of those hooked in the jaw. Dextrase and Ball (1991) described the rate of mortality in Lake trout (*Salvelinus namaycush*) due to hooking impact on different positions and indicated fish hooked in the gills recorded 100% mortality. The location and degree of injury as well as the size of the fish are all significant factors in determining the survival of fish. (Barwick, 1985; Wertheimer, 1988; Clapp & Clark, 1989; Schaefer, 1989;).

3.2.3 *Fishing method/process and mortality*

Wright (1970) suggested that rapid hauling in of lines, roughly shaking fish off the hook or clubbing them to make their removal easier, must all increase mortality.

3.2.4 *Temperature and mortality*

There are several studies indicating that mortality was higher during the summer months when compared to colder periods. Muoneke (1993) recorded that the hooking mortality was significantly higher in summer than winter. Storck and Newman (1992) and Bennett et al (1989) also reported that the hooking mortality increased as water temperature increased. However, in the case of nonanadromous trout the water temperature did not show a statistically significant relationship with mortality (Taylor and White, 1992) and the same result is recorded by Nuhfer and Alexander 1992 in brook trout.

3.2.5 *High resistance of certain species against hooking impact.*

Some species have remarkably high degrees of resistance against hooking impact and therefore it was found their survival rate after hooking was very high. In the case of white crapie, *Pomoxis annularis*, and spotted bass, *Micropterus punctulatus,* Muoneke (1992) observed less mortality and suggested a strategy necessitating release of some portion of the catch as a management plan for the fishery. Bugley and Shepherd (1991) recorded zero a mortality rate in black sea bass, *Centropristis striata,* captured and released by anglers. Also Fletcher (1987) found significantly low mortality rate (1.1%) in walleyes (*Stizostedion vitreum)* caught on live and artificial bait.

3.2.6 *Fish size and mortality*

Some studies have indicated hooking mortality is inversely related to fish length. Wertheimer et al. (1989), and Loftus et al. (1988) found that the probability of hooking mortality is high in small size classes of fish. However, Storck and Newman (1992) found no relationship with size and mortality rate in tiger muskellunge (female muskellunge *Esox masquinogy* X male northern pike *Esox lucius*).

3.3 Previous studies on the comparison between hook and lines and nets.

French and Dunn (1973) summarise the extensive evidence that salmon caught in high-seas gillnets and tagged are rarely recaptured, the immature ones almost never, whereas those taken on longlines and tagged are recovered with much greater frequency, though by no means as frequently as would be expected of uninjured and untagged fish.

3.4 Studies on stress impacted by fishing in general

3.4.1 *Stress related mortality*

Stress response is a mechanism which enables fish to avoid or overcome potentially threatening, noxious or harmful situations (Pickering, 1993). The fish's reaction to a particular stressor will depend on the species, and the type of stressor and it's severity (Wedeymeyer et al., 1990). Studies on a range of teleost species have established that stress results in activation of the hypothalamo-pituitary-internal axis and release of the steroid cortisol into the blood stream. Plasma concentrations of cortisol, resulting from stress, have subsequently been shown to be reliable index of the physiological response to stress (Donaldson 1981). In addition to causing changes in corticosteroid levels, capture and handling stress are usually associated with marked increases in plasma and muscle lactate concentrations (Barton and Iwama, 1991). The metabolic acidosis resulting from stress and/or exercise is implicated in post-capture mortality in a number of species (Graham et al., 1982; Wood et al., 1983; Ferguson and Tufts, 1992).

Table 2 Mortalities recorded from Line Fishing

Fishing Gear	Species	Mortality(%)	Comments	References
Hooks and lines.	*Oncorh-ynchus* sp.	12-69	Catch and release mortality estimates.	Vincent-Lang et al., 1993.
Hooks and lines.	*Oncorh-ynchus* sp.	34-52 40-86	Coho salmon, Chinook salmon.	Parker et al., 1959.
Hooks and lines.	*Salmo* sp.	0	No mortalities after 3 days but measurable stress.	Wydowski et al, 1976.
Hooks and lines.	Rainbow trout	39 3-5	Hook swallowed corn bait, artificial lure.	Barwick, 1985
Hooks and lines.	Cutthroat trout	0.3,3	One time hooked mortality,multiple hooking.	Schill et al, 1986.
Hooks and lines.	Trout	0-8.6	Angling mortality	Dotson.1982
Hooks and lines.	Small-mouthed bass	0,11	Artificial lures, live bait.	Clapp and Clark, 1989.
Hooks and lines.	*Esox* sp.	3	Angling mortality.	Schwalme and Mackay. 1985.
Hooks and lines.	Chinook salmon	9-32	Trolling, small fish had higher mortalities	Wertheimer, 1988.
Hooks and lines.	Pacific salmon	41	Trolling,34% immediate mortality and 7% delayed mortality.	Milne and Ball, 1956
Hooks and lines.	Brook trout	4.3,8.3	4.3% mortality for lures with single hooks,8.3% for lures fitted with treble hooks.	Nuhfer and Alexander 1992.

Table 2 cont.

Hooks and lines.	Blue-gills	1.05,25.3	Post release mortality, higher rate in summer.	Muoneke, 1993.
Hooks and lines.	Brook trout	10	All mortality in fish injured in critical area (gills,deep mouth and stomach)	Dextrase and Ball, 1991.
Hooks and lines.	Sea bass	4.7	All mortalities occurred in fish hooked in the oesophagus.	Bugley and Shepherd, 1991.
Hooks and lines.	Chinook salmon	25.7	Trolled fish caught incidentally while targeting coho.	Wertheimer, 1988.
Hooks and lines.	Wall-eyes.	0.8	All mortalities from foul hooked fish.	Schaefer, 1989.
Hooks and lines.	Wall-eyes.	0-10	Zero mortality for fish captured with lures.	Payer et al, 1989.
Hooks and lines.	Wall-eyes.	1.1	Post release mortality after 12 days.	Fletcher, 1987.
Hooks and lines.	Lake trout.	14.9	Higher mortality was noted in smaller fish.	Loftus et al, 1988.
Hooks and lines.	Bass	0.8-47.8	Post release mortality noted in first 6 days after release.	Schramm et al, 1987.
Hooks and lines.	Trout	NA	A meta analysis of hooking mortality of nonanadromous trout.	Taylor and White, 1992.

The types of stress fish are subjected to during capture by different commercial fishing gear will depend on the fishing method but also include confinement, over crowding, and severe exercise. Various authors have shown that capture and confinement in fishing gears results in increased levels of stress (parker et al., 1959; Wardle, 1971; Wydoski et al., 1976; Swift, 1983; Wells et al., 1984, 1987; Hopkins and Cech, 1992; Pankhurst and Sharples, 1992).

3.4.2 *Suppression of reproductive endocrinology and susceptibility to naturally occurring pathogens.*

Several studies have indicated that physiological stress has an inhibitory effect on reproductive processes in fish. Stress-induced increases in plasma cortisol are associated with depression of plasma androgens and oestrogens in brown trout (*Salmo trutta)* (Pickering et al., 1987; Sumpter et al., 1987) and snapper *(Pagrus auratus)* (Carragher and Pankhurst, 1991). Most of the research associated with fish's reactions to various stressors has been conducted in the aquaculture industry where fish held in confinement may suffer chronic stress due to over crowding (Wedeymeyer, 1976), confinement (Barton et al., 1980), and handling (Strange et al., 1977). Pickering (1993), describes in depth the effect of chronic stress on salmonoids, including; increased susceptibility to naturally occurring pathogens, suppression of reproductive endocrinology and the maturation process.

3.5 Summary.

The review of literature demonstrates that damage and stress impacted by fishing are major causes of mortality. However, handling time, fish size, temperature (season) and fishing methods are the deciding factors for the degree or the extent of the mortality. The present investigation considered all these important parameters in its design and methodology.

4 METHODS

The mortality of undersize fish can occur either during the fishing operation (pre-release mortality - PRRM) or after releasing the fish. (post release mortality - PORM). Both types of mortality have been studied in the commercial haul net fishery and the recreational line fishery.

Monitoring of both sectors was undertaken throughout the year, to incorporate the seasonal fishing operations for each sector. The following information was used to determine the relative level of sampling:

* South Australian commercial net fishery

  Seasonality of South Australian fishing effort on garfish by major areas was obtained from summarised catch and effort information for the period 1983-86 (Jones and Kangas,1987).

* Recreational line fishery

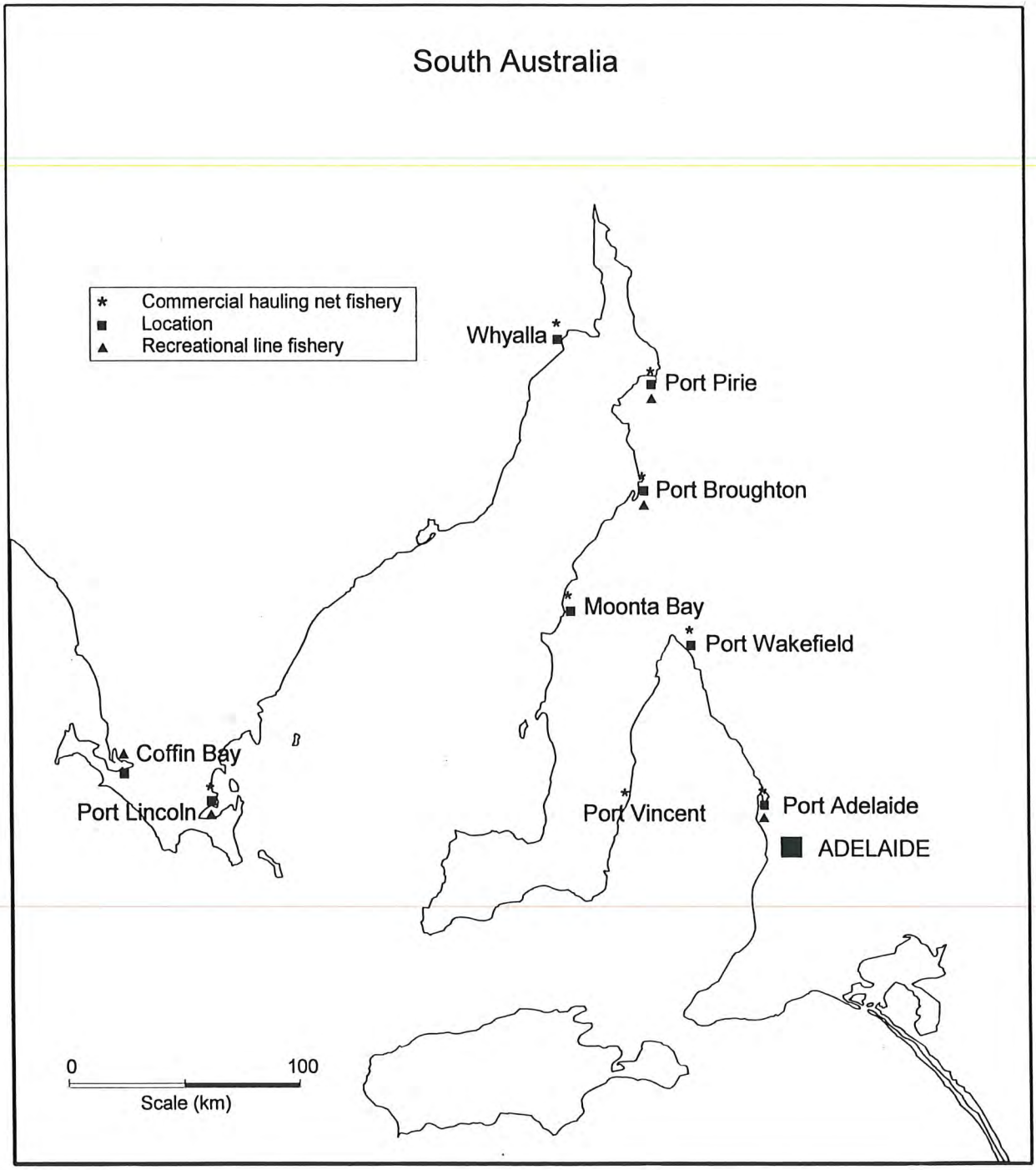
  Data on seasonal recreational fishing effort for a number of areas including Coffin Bay (Jones, 1983), Pt.Lincoln bays (Jones, 1986) and Franklin Harbour (Jones and Retallick, 1990), and Metropolitan waters (McGlennon and Evans, 1992) were used to monitor the recreational line fishery

The haul net fishery effort (targeting garfish) is traditionally low during November and December. The commercial net fishery therefore was not sampled for these two months. Although recreational fishing effort fluctuated markedly throughout the year, it was considered that sampling of this sector should be throughout the year because of relatively high effort during November and December. The areas chosen for studying the impact of recreational fishing were Pt.Lincoln, Coffin Bay, Whyalla, Moonta Bay and Pt. Adelaide. In addition to these areas, Pt. Broughton, Pt.Pirie and Pt.Wakefield were included for the haulnet fishing survey (**fig 3**). The timetable for sampling of both fishing sectors and the boatdays sampled are given in **Table 3.**

Table 3 Sampling schedule, including the number of boatdays monitored for the recreational line and the commercial haul net fisheries.

Fishing Method	Boatdays monitored in different season				
	Jan-Mar 1	Apr-Jun 2	Jul-Oct 3	Nov-Dec 4	Total
Haulnet	24	16	20	-	60
Rec.line	20	17	13	12	62

Fig 3 Sampling Centres



4.1 Impact of the hauling net fishery (targeting garfish) on the mortality of undersized King George whiting.

4.1.1 *The estimation of numbers of undersize King George whiting caught in the net fishery and mortality rate (pre-release mortality - PRRM)*

Commercially licenced marine scalefish fishers (with a net endorsement) were selected at random to be surveyed. On board monitoring was carried out during normal commercial haul net operations. The netting operation method has been described in Jones et.al, (1990). A total of 126 fishing days were monitored. For each net fishing day surveyed, the following parameters were collected:

* The number of times per day the net was 'shot' (ie. set from the boat into the water and recovered).

* The total fish handling time (t) was calculated by recording the starting time of the ring shot or power haul shot (t1), the time of the completion of the shot (t2), the time the net pocket remained on the deck(t3), the time taken for fish sorting to be completed (t4) and the time of release of the undersize fish (t5).

* Size frequency distribution of the species in the catch: Both size composition and quantity of total commercial catch, and of the by-catch of undersize King George whiting.

* The mesh and ply sizes of the hauling nets used.

* External injuries and status: One of the three following categories of injury was recorded for each undersize King George whiting incidentally captured and then released. These were;
  (a) slight damage, including scratching and minor scale loss;
  (b) more severe injuries, including redness, bruising or open wounds with musculature clearly visible, damaged jaws; and
  (c) dead fish.

4.1.2 *Estimation of mortality rates of undersize King George whiting after incidental capture and release by net (post-release mortality - PORM).*

King George whiting below the legal size limit of 28cm were captured by commercial net fishers in the Port Adelaide area, using nets which would normally be used when targeting garfish. The Port Adelaide region was selected due to the availability of undersize fish in this region for all the seasons sampled and also its proximity to the holding facility. The external injury status was recorded as per the normal sampling method. The live undersize fish were then collected and transported, in an insulated 1,000lt fibreglass container, to the South Australian Aquatic Sciences Centre at West Beach. Here the fish were held for a further 30 days in 40,000lt holding tanks and their condition monitored.

Tanks were divided into 4 equal sections, with fish caught by each method held in the one tank but in separate sections. Tanks were allowed to dry and cleaned between experiments. The fish were fed on cockle meat at the rate of approximately 5% of body weight daily. Wide fluctuations in food requirements were noted depending on season and water temperature. No treatment was used once the fish were placed into the tanks and daily condition, feeding response and mortalities (if any) were recorded.

4.1.3 *Control*

As a control experiment, undersize fish of the same size group were caught at the same time in a fine mesh (12mm woven mesh beach seine) net. Fish in good condition (with no obvious scale loss or bruising) were then transported to the laboratory and monitored in a similar way to the fish captured by commercial hauling net and recreational hook and line.

4.2 Impact of the recreational line fishery on the mortality of undersized King George whiting.

4.2.1 *Estimation of the catch of undersize King George whiting by recreational line fishery and mortality rate(Pre-release mortality PRRM).*

On board observations of recreational line fishing activities were carried out at major fishing ports. Most boats sampled were affiliated with a fishing club in the local area of operation. The number of boats surveyed on any one day varied between 2 and 8. The external injuries and mortalities of incidentally captured, and subsequently released, King George whiting below the legal minimum size limit of 28cm were recorded. A total of 48 days observation of recreational line fishing was conducted. The following parameters were recorded:

* Hook size used
* Handling time before release of the fish and the external injuries.

These injuries were classified as

(a) minor injuries, including hooking injuries around the lips with little or no bleeding and bruising;

(b) serious injuries near the gills or eyes, swallowed hooks and severe bleeding ;and

(c) dead fish.

4.2.2 *Estimation of mortality rates of undersize King George whiting captured by recreational line fishing (post-release mortality - PORM).*

As in the commercial net study, the Port Adelaide area was selected for the capture of undersize King George whiting by the recreational hook fishery due to the availability of undersize fish and the proximity to the South Australian Aquatic Science Centre at West Beach. Undersize King George whiting were retained from recreational fishing operations and the external injury status was recorded. Fish were held in 'corfs' attached to each boat and subsequently transferred to a

400lt tank on board the research boat. Live undersize fish were then collected and transported in a 1,000lt insulated fibreglass container to the West Beach facility . Here they were transferred to 40,000lt holding tanks for an additional 30 days where their condition was monitored.

The control experiment described for the commercial net fishery was also used to compare the survival rates of undersize King George whiting captured by hook.

Preliminary results from the recreational line fishery survey, currently being carried out by SARD was used for the estimation of undersize fish mortality inflicted by recreational line fishing sector.

4.3 Stress analysis

Corticosteroid hormone (cortisol) levels in blood were used to compare the degree of stress in King George whiting after capture by either net, or hook and line, fishing methods. Investigations on several teleost species have established that stress results in activation of the hypothalamo-pituitary-interrenal axis, and the subsequent release of corticosteroid hormones into the blood stream (reviewed by Barton and Iwama, 1991). Plasma concentrations of cortisol resulting from stress have subsequently been shown to a reliable index of the physiological response to stress (Donaldson, 1981).

To understand the fishing impact of both commercial hauling nets and recreational hook and line two series of experiments were carried out.

4.3.1 *Sampling of Blood*

The blood samples from undersize fish, which were caught by either commercial net or recreational line fishing methods, were collected as soon as possible after capture, prior to transport. The fish were then transported to the South Australian Aquatic Sciences Centre and held in 40,000 lt holding tank. The blood samples were taken in 30 minutes intervals for the first two hours (0, 30, 60, 90 and 120 minutes). Further blood samples were taken at 24 hour intervals up to 96 hours (24, 48, 72 and 96 hours). At each interval, 6 fish were sampled and then removed to a separate tank.

The following method was used to take blood both at sea and in the laboratory. The whiting were held in a wet cloth and the needle of a graduated syringe was introduced into the caudal vein and the blood (a maximum of 2ml per fish) slowly withdrawn. These samples were refrigerated for 24hrs and then the plasma was separated by centrifuge. Plasma samples were stored frozen until further analysis. Since the fish were relatively small (average 22-25cm T.L.), fish were sampled once only.

4.3.2 *Cortisol Measurement.*

The plasma fraction from the blood samples was separated by centrifuge and stored frozen until analysis. Cortisol was measured in plasma by radioimmuno assay using Amerlex cortisol RIA kit and gama counter at the University of Adelaide Medical School. The assay protocol and reagents are given in the cortisol kit, which was produced by Kodak clinical diagnostics in 1992.

4.4 Data analysis

Filed and experimental data were entered on Lotus 123 software. These data have been transferred into SAS software produced by the SAS Institute Inc. Cary, NC, USA for processing and sorting the information.

The pre release mortality (PRRM) inflicted by haulnet fishing was estimated using undersize catch per unit effort ratio calculated from the field survey data(total effort, undersize fish caught, mortality during fishing operation) considering three seasons of the year. This sample ratio was raised against total effort information provided by the haulnet fishers through GARFIS data base system.

The total number of undersize fish from the recreational sector was obtained from the preliminary results of a recreational survey currently being carried out by SARDI(McGlennon et al, FRDC project 93/249). PRRM was estimated based on the sample ratio.

Post release mortality (PORM) was estimated based on the laboratory experiments conducted laboratory . The experiments were carried out in triplicate for each season including control, haulnet, recreation line sector. The results from the triplicates experiments were pooled together to obtain the ratio of PORM. Experimental mortality rate for each category was used to calculate the annual mortality of undersize fish caught and released by each fishing method. The control result was treated as natural mortality.

4.5 Estimation of number of undersize fish caught

Value of N_R was extracted from the preliminary results of recreational survey currently being carried out by SARDI.

$$N_H = N_{HS} \times \frac{B_H}{B_{HS}}$$

$$CM_R = C_{EM} \times (N_R - \frac{PRRM_R}{C_{EN}})$$

$$PRRM_H = M_{HS} \times \frac{N_H}{N_{HS}}$$

$$PORM_H = M_{HS} \times (N_H - \frac{PRRM}{N_{HE}}) - CM_H$$

$$PRRM_R = M_{RS} \times \frac{N_R}{N_{RS}}$$

$$PORM_R = M_{RE} \times (N_R - \frac{PRRM}{N_{RE}}) - CM_R$$

$$CM_H = C_{EM} \times (N_H - \frac{PRRM_H}{C_{EN}})$$

where as:

$PRRM_H$	=	Estimated pre release mortality for haulnet sector.
$PRRM_R$	=	Estimated pre release mortality for recreational line sector.
$PORM_H$	=	Estimated post release mortality for haulnet sector.
$PORM_R$	=	Estimated post release mortality for recreational line sector.
CM	=	percentage of control mortality.
CM_H	=	Estimated natural mortality for haulnet section.
CM_R	=	Estimated natural mortality for recreational line section.
B_{HS}	=	Boat days surveyed for haulnet fishing.
B_H	=	Boatdays fished by haulnet fishers targeting garfish.
N_{HS}	=	Number of undersize fish caught during the haulnet fishing survey.
N_H	=	Total number of undersize fish caught by haulnet fishers.

N_{HE} = Number of undersize fish used for the PORM experiment for haulnet fishing.
M_{HS} = Mortality recorded during haulnet survey.
M_{HE} = Mortality recorded during the course of PORM experiment for haulnet fishing.
B_{RS} = Boat days surveyed for recreational fishing.
B_R = Boat days fished by recreational fishers.
N_{RS} = Number of undersize fish caught during the recreational line fishing survey.
N_R = Total number of undersize fish caught by recreational fishers.
N_{RE} = Number of undersize fish used for the PORM experiment for recreational line fishing.
M_{RS} = Mortality recorded during recreational line fishing survey.
M_{RE} = Mortality recorded during course of PORM experiment.
C_{EN} = Number of undersize fish used for control experiment.
C_{EM} = Mortality recorded during control experiment.

5 RESULTS

5.1 Impact of haul net

5.1.1 *Catch and effort in haul net fishery*

During 1994, commercial net fishers expended 2402 boat days and produced 327.08 tonnes of King George whiting when targeting garfish. About 43% of the total effort was applied during the first season (January to March) whereas 26.7% of the total effort was applied during the second season. **Fig-4** shows the details of catch and effort during 1994. On comparing the catch levels of the first two seasons, it was noted that approximately similar quantities of whiting, garfish, and other fish were caught. However, the effort applied in the second season was equivalent to half of the first season. Similarly, on comparing the average effort expended by net fishers per month for 1994, it was found that about 347.7 boatdays per month were fished in the first season, against 214 boat days per month during the second season. However, during the third season the effort applied further reduced to 137.5 boat days per month and 83.5 boatdays per month for November and December.

5.1.2 *Garfish catch and effort relationship and availability*

The garfish hauling net was used mainly to target garfish. This section of the analysis was carried out particularly to examine if a relationship existed between the effort applied and the quantity of garfish caught. **Fig-4** clearly indicates that there was no proportional relationship between the garfish catch and effort as the total quantity of garfish caught during the first and second season varied widely independent of the effort applied. The availability of the fish at any given time can be understood by the catch per unit effort. Average catch of garfish per unit effort during 1994 was 91.7Kg per boatday. During Season 1, the fishers applied 43% of their total effort and returned about 74.62Kg per boatday. However, in Season's 2 and 3, the fishers applied comparatively much lower levels of effort (26.7% and 22.89%) which resulted in catches of 123.16Kg and 102.70Kg per boatday respectively. The last two months of the year produced only 41Kg per boatday. This clearly shows that the extra effort applied by the fishers, during season 1 did not produce any surplus catch and that for the 3 main seasons, at relative levels of effort, CPUE for garfish is not proportional .

Fig 4 Haulnet catch and effort details in 1994

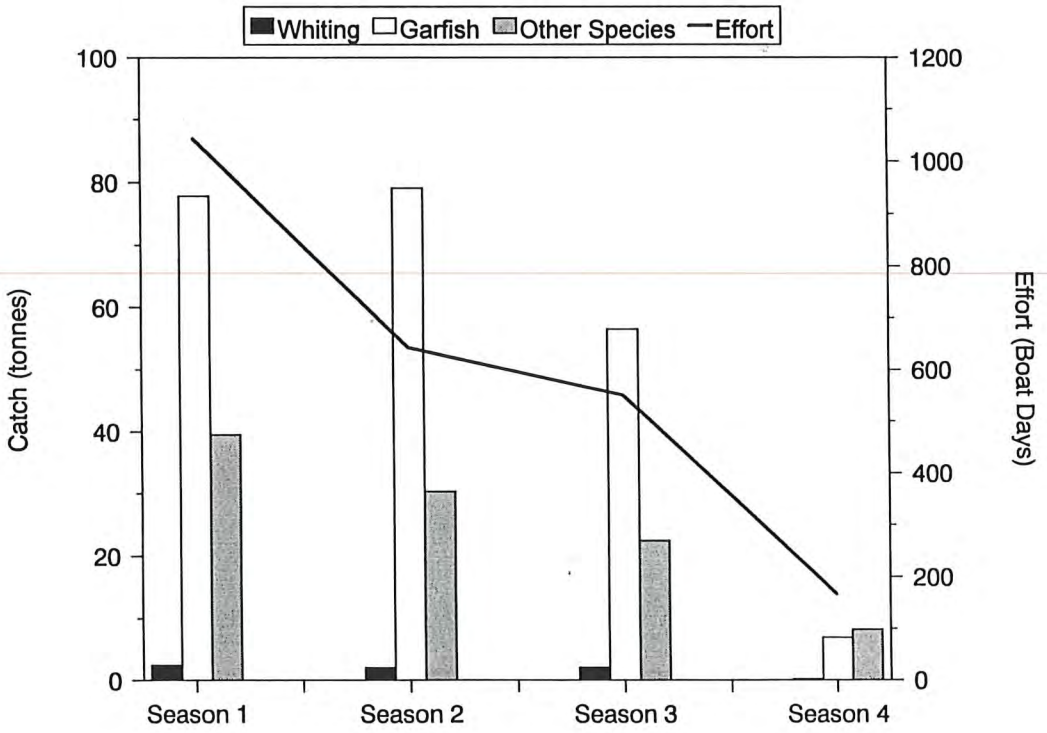
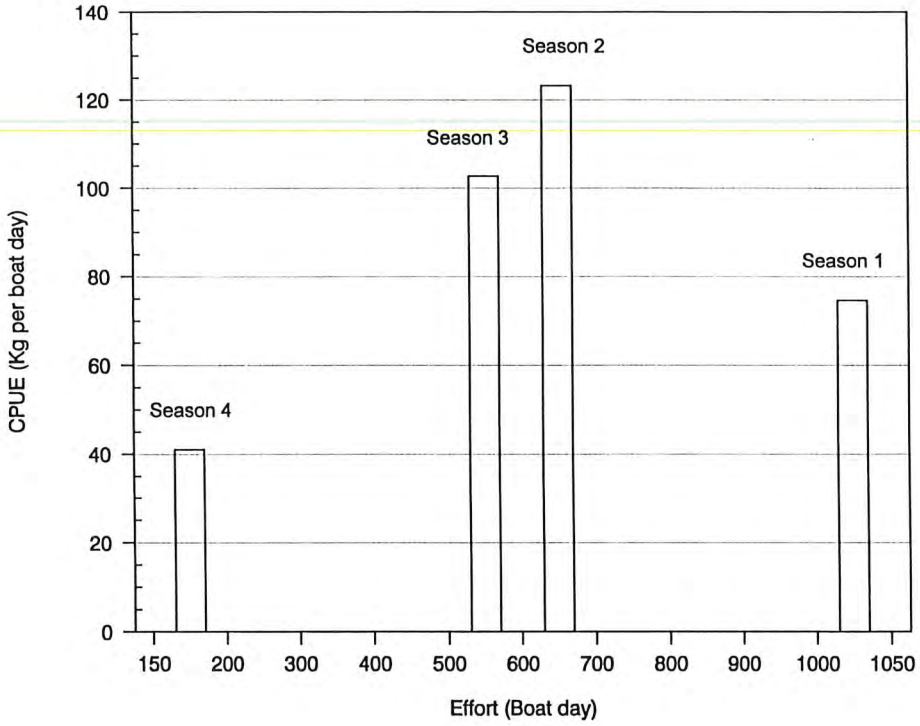


Fig. 5 Garfish Catch per Unit Effort in 1994



5.1.3 *Legal Size King George whiting as by-catch and effort relationship and availability.*

On average during 1994 the haulnet fishers, whilst targeting garfish, caught 2.7Kg of legal size King George whiting per boatday as a by-catch. Seasons 2 and 3 accounted for a higher catch ratio of 3.01Kg and 3.69Kg per boatday respectively. Conversely, Season 1 produced only 2.27Kg per boatday although a significantly higher effort was applied. The off-season catch was less than a kilo per boatday. Looking into the total catch and effort of each season, the catch rate independently varied against the effort applied, that is, the King George whiting by-catch was not proportional to the effort applied.

5.1.4 *Other fish (tommy ruffs,mullet, squid, leather jacket and salmon) as by-catch, and effort relationship and availability.*

The by-catch of other fish species (mentioned above) formed a supplementary income for the haulnet fishers. **Fig-4** clearly indicates that the catch for these species was directly proportional to the effort. The by-catch was relatively consistent throughout the year and averaged 41.79Kg per boatday. The catch ratio did not vary appreciably between seasons.

5.1.5 Undersize King George whiting caught in haul nets.

* *Undersize fish distribution*:

The species and sizes of fish caught in fishing gear is principally determined by the species and size selective characteristics of the gear. The capture of juvenile fish in many commercial fisheries is controlled by restricting the use of gear that prevent the escape of juvenile fish. The undersize fish caught in haul nets mainly depends on the selectivity, which is related to mesh size. The legal minimum mesh size allowed for haul nets is 3cm. However, our observation revealed that the fishers used mesh sizes varying from 2.6cm to 3.3 cm mesh. Among all the nets that were examined, there was no uniformity of mesh size over a complete net. A typical 600m haulnet consisted of several panels of both old (15 years and more) as well as new net, which varied in ply size as well as mesh size. Normally, the pocket was made of heavier ply and the hauling 'wing' end of lighter ply. Another important aspect noticed was that frequently the material used for making the net varied from panel to panel. Therefore, when the nets were immersed in water and the ply size measured, the different construction material, varying ply size and age of the net meant individual panels in the net acted very differently from each other. The ultimate result was that a single net had different selectivity characteristics. Therefore, a wider range of fish size groups were vulnerable to meshing in haul nets. The size distribution of undersize KG whiting is shown in **figs.6, 7 & 8**. The size group of 17 to 22 cm, which is most vulnerable to meshing in garfish haulnets, dominated during the first season (January to March). In the next season (April to June) the dominant group observed was the size group of 23cm to 26 cm. During July to October, the size group of 26 to27cm fish dominated the undersize catch.

Fig 6 Size frequency distribution of King George whiting in Season 1-Haul net

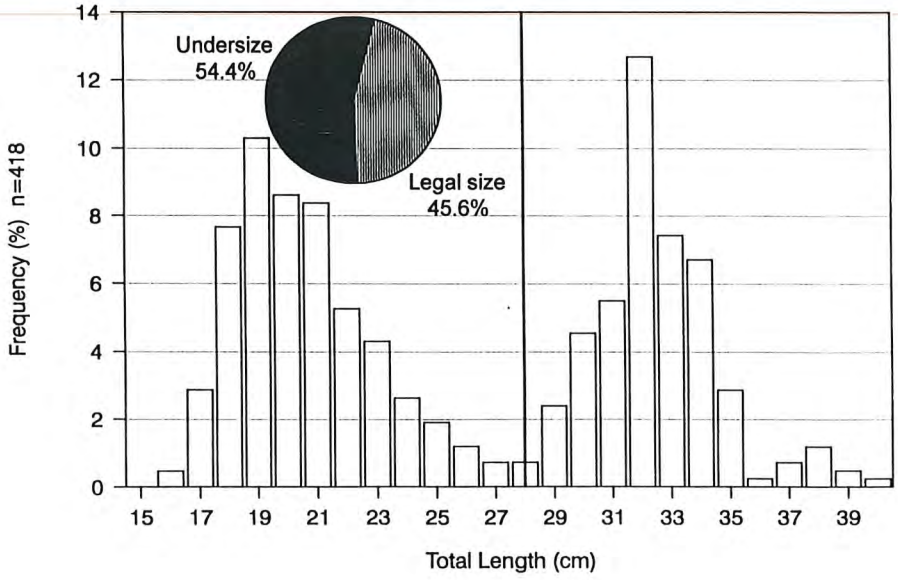


Fig 7 Size frequency distribution of King George whiting in Season 2-Haul net

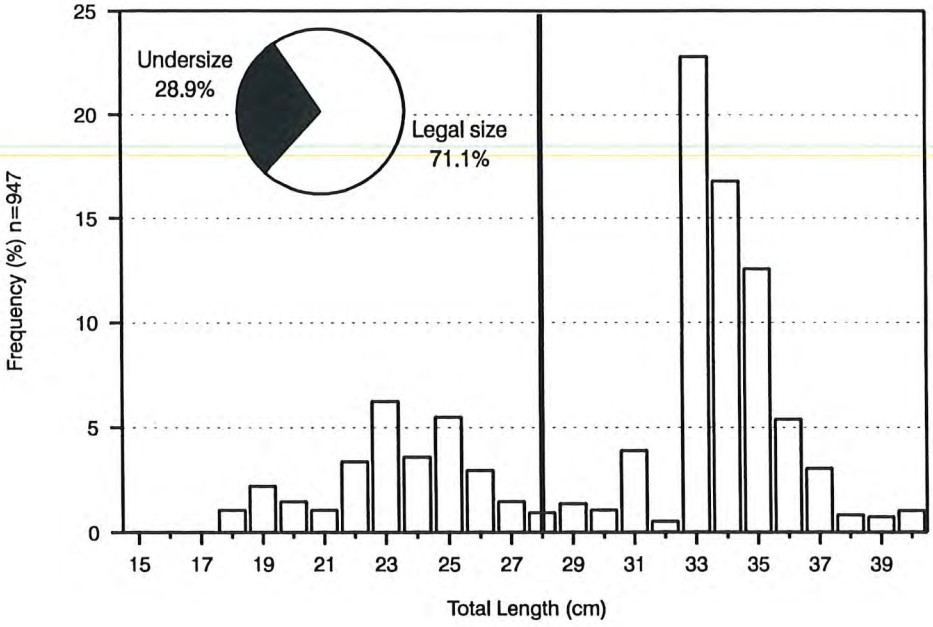
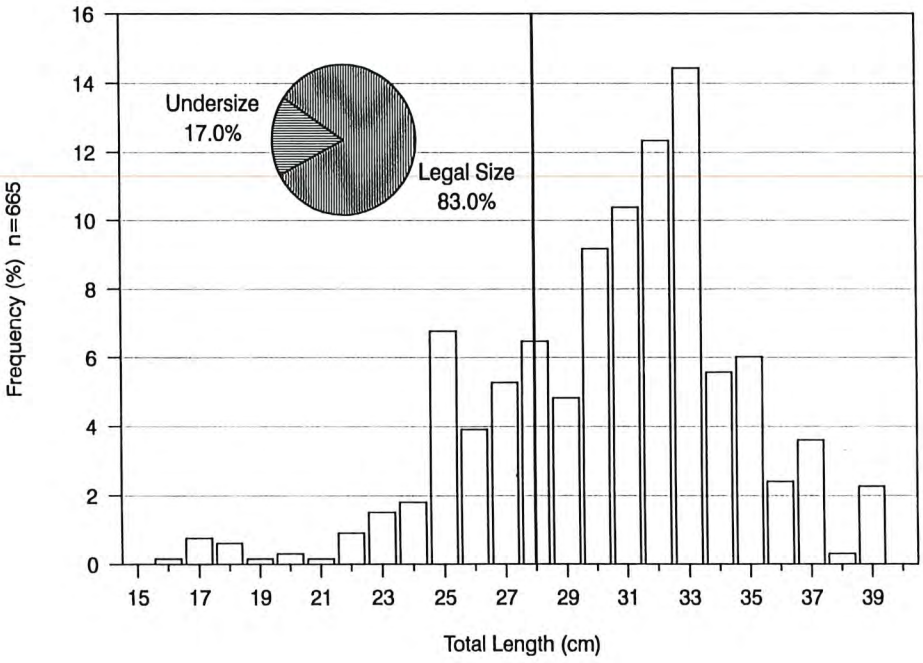


Fig 8 Size frequency distribution of King George whiting in Season 3-Haul net



Studies undertaken in King George whiting nursery areas in South Australia (Jones et al 1989)upport these results.

* *Undersize and legal size ratio*:

The percentage of undersize fish caught in haul nets varied from 54.3% in season 1 to 17% in season 3 **(Figs.6,7 & 8)**. Although Season 1 had a greater proportion of undersize King George whiting than legal size fish, the highest rate of undersize fish in terms of the number caught per boatday was recorded in Season 2 (**Table 4**). In 1994, it was estimated that a total of 23967 undersize King George whiting were caught in haul nets.

5.1.6 *Pre release mortality rate (PRRM)of undersize King George whiting .*

The following section deals with fishing impact in terms of injury and mortality of undersize fish during the fishing operation.

* *Ratio of fish caught in the pocket compared with fish meshed*:

The highest percentage (51.55%) of undersize fish meshed in the nets was recorded in Season 1. This was mainly because of the availability of 17 to 22 cm fish which were vulnerable to meshing in garfish nets during that period. The seasonal size distribution shown in **Fig 6** clearly indicates that the 17 to 22 cm size group dominated the undersize population during January to March. The percentage of undersize fish meshed considerably reduced during seasons 2 and 3, with 17.15% and 15.93% respectively.

* *Mortality rate and injury status*

In general, the mortality rate was found to be comparatively higher in fish that had meshed than fish caught in the pocket (**Fig.10**). In Season 1, a high mortality rate (24%) was observed compared with the other two seasons. It was calculated that 2368 undersize fish were killed during the first season. This was mainly due to the vulnerability of a high percentage of undersize fish to the garfish haulnets during the first season and 17% of the mortality came from the meshed section. As indicated in **Fig. 9,** the mortality rate declined in the latter half of the year (Season 2 and 3) and the availability of the undersize fish also decreased. It was estimated that 879 and 110 undersize fish were killed during the second and third seasons respectively. This clearly established that Season 1 (January to March) was the most vulnerable period in terms of undersize fish mortality and during the rest of the year, the impact of haul nets with regards to pre-release mortality was relatively low. A total of 3357 undersize fish were killed during the haulnet operations, of which 70 % of the mortality was inflicted during the first three months of the year.

Fig 9 Pre release mortality and injury status during haul net fishing

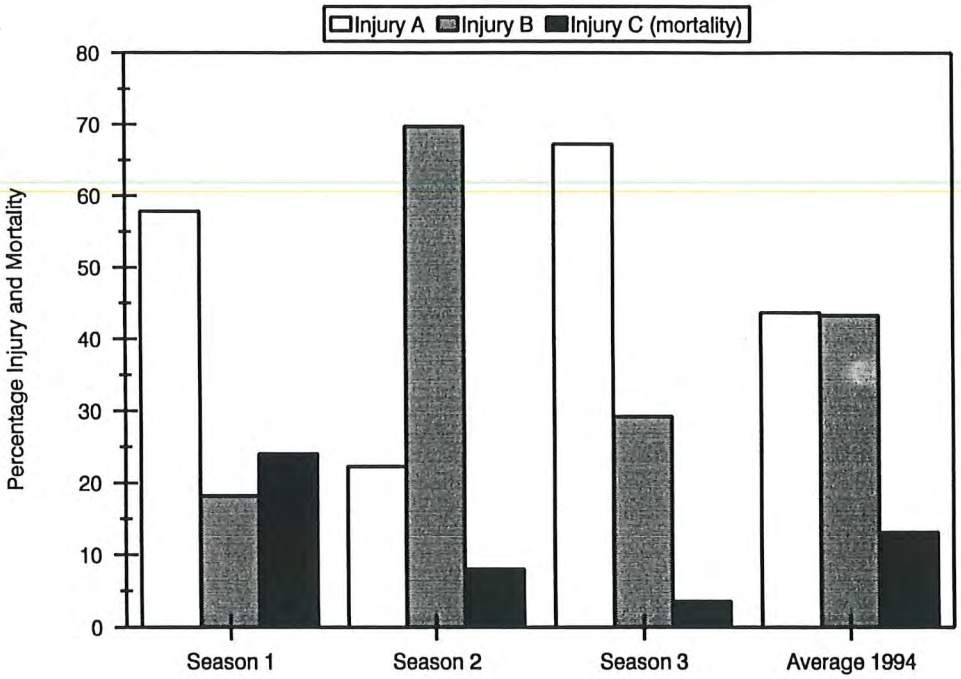
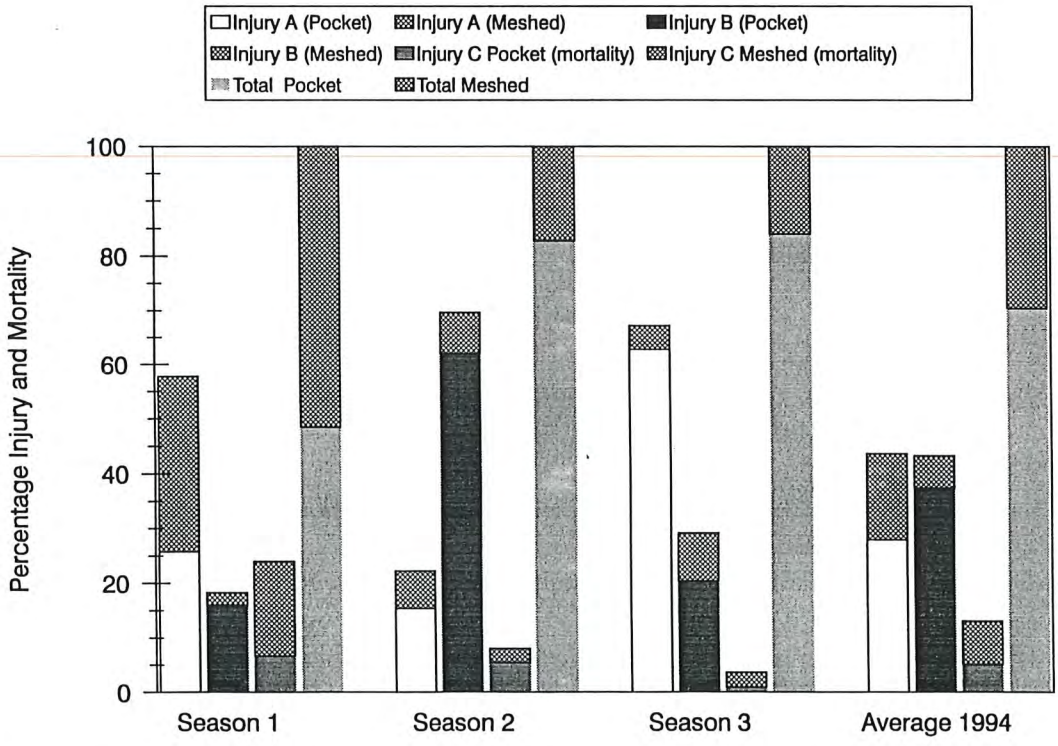


Fig10 Pre release mortality and injury status in fish captured in pocket compared with meshed fish.



As explained in the methodology, the fish were classified into two groups (a and b) according to the severity of the visible injury/condition and group c represented mortalities. Injuries to under size fish in haul nets could result from several factors. Fish which are driven by the net and make several attempts to force through the net could mesh in the net, or result in bruise mouth parts and head, damaged operculum or loss of scales. A typical power haul shot took 2 hours to complete and fish which had encountered the net during the first stages of the operation could have been driven for the full duration of the shot. This increased handling time leads to stress and injury to fish. The haulnet fishing operation was observed to attract predators to the area. Large numbers of cormorants were attracted towards the netting area and were observed feeding on the fish that were returned to the sea. It was also noticed that squid and Australian salmon captured in the net continued to feed and may have been preying on undersize fish inside the net. Fish were also exposed to varying times of confinement once the shot had been completed and the pocket of the net was alongside the net boat, while the catch was sorted and transferred to the boat. Undersize (and legal size) King George Whiting were observed to remain low down in the pocket and were usually one of the last species to be removed , especially if garfish catches were good. This behaviour prolonged the time the undersize King George whiting spent in confinement and probably increased the stress and decreased survival rates after release.

Table-4 Sample results of field Survey (PRRM) and Laboratory Results (PORM) Haul Net

Season	PRRM Field studies				PORM Experiment		
	Boat Days	No caught	Mort No.	Mort %	No. of fish used in experiment	Experiment Mortality	Mort %
1	24	227	54	23.8	48	5	10.4
2	16	274	22	8.0	73	9	12.3
3	20	113	4	3.5	77	8	10.3
Total	60	614	80	13.0	198	22	11.1

Fig 11 Post release mortality and injury status in haulnet fishing

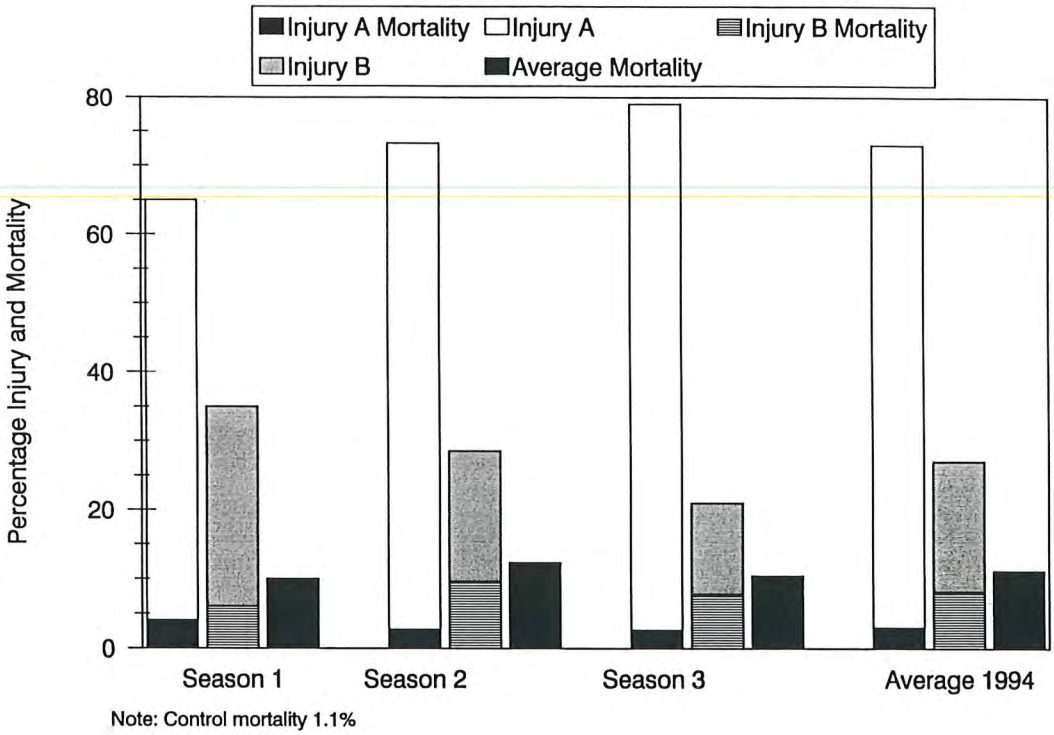


Table-5 Control Experiment Results

Season	No. of Fish Used	Mortality	Mortality %
1	88	1	1.1
2	93	2	2.2
3	90	0	0
Total	271	3	1.1

5.1.7 *Post release mortality (PORM) of undersize King George whiting caught by the haulnet sector.*

This section deals with the estimation of mortality rate of undersize fish killed after being released back into the sea from the haulnet operation or post release mortality (PORM). The results of the experiments conducted to estimate PORM are shown in **Table-4**. The results indicate the PORM percentage was similar for all seasons, ranging from 10 to 12%. An average of 11% PORM was recorded for haulnet fishing.

* *Mortality pattern and general behaviour of experimental fish.*

Among the fish that died during the course of the experiment, 54.6% of the mortality occurred within 24 hours of capture and 97% of the mortality happened within 72 hours. Experimental fish showed stress symptoms during the first three days. Although the majority of the fish started feeding after 48 hours of transfer from the sea, sluggishness and stress colouration were observed for up to five days and in some cases up to ten days. Once the initial three days were passed,the probability of mortality was low (3%). In tank conditions, the injured fish began to recover and the wounds healed completely. The highly stressed fish developed secondary infection and 90% of the fish that died had secondary infection. Most fish held after capture by net showed some signs of fungal infections on the fins and tail. The majority of the meshed fish were found to be infected around the gill area, which was the primary cause of mortality in this group.

Of the 198 fish that were utilised for the PORM experiments during the three seasons, 73% (145) were injury A and 27% (53) were injury B. The fish that belonged to injury B were clearly identifiable during the initial week because they carried visible injuries. As 97% of the post release mortality happened within the third day, the dead fish were easily segregated after inspection and their respective conditions were recorded. Experimental results indicated that on average, 30% of injury B and 4% of injury A fish died. An average of 1.1 % mortality was recorded from the control experiment. Therefore,if the fish were released in injury A, the survival rate could be as high as 95%.

Based on these results, and after subtracting the average control mortality of 1.1%, the PRRM for the haulnet fishery was estimated at 2062 undersize King George whiting during 1994.

5.1.8 Total Mortality

Based on the laboratory results of PORM and data obtained from field monitoring and fishers catch statistics, a total mortality of undersize King George whiting for the haul net fishery was estimated to be 5419 (3357 PRRM + 2062 PORM) fish . It is important to mention here that the laboratory experiments may not give an accurate PORM rate because of the differences in environmental and predator-prey conditions between the laboratory and the sea.

Fig 12 Size frequency distribution of King George whiting in recreational line fishing catch during Season 1

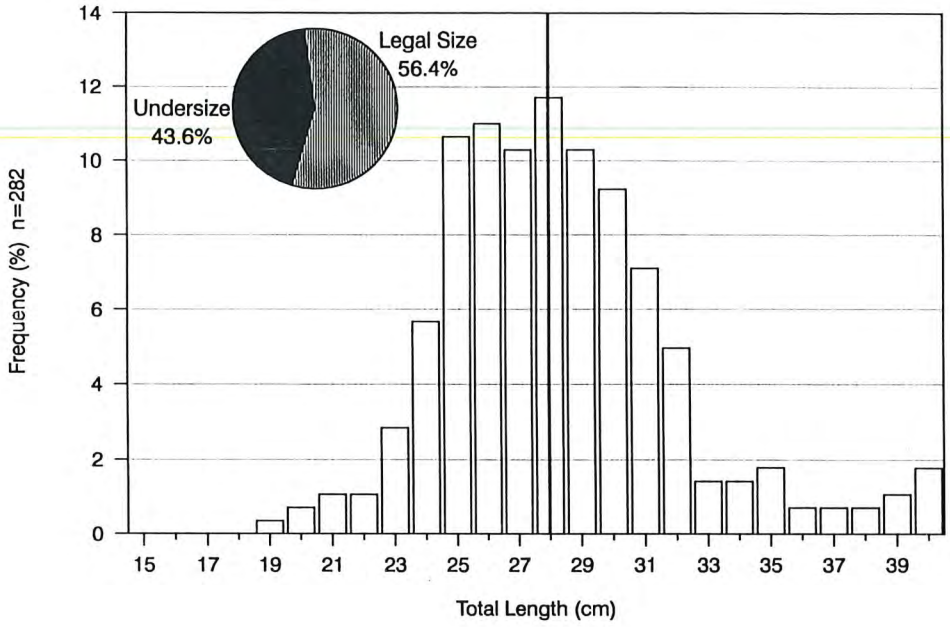


Fig 13 Size frequency distribution of King George whiting in recreational line fishing catch during Season 2

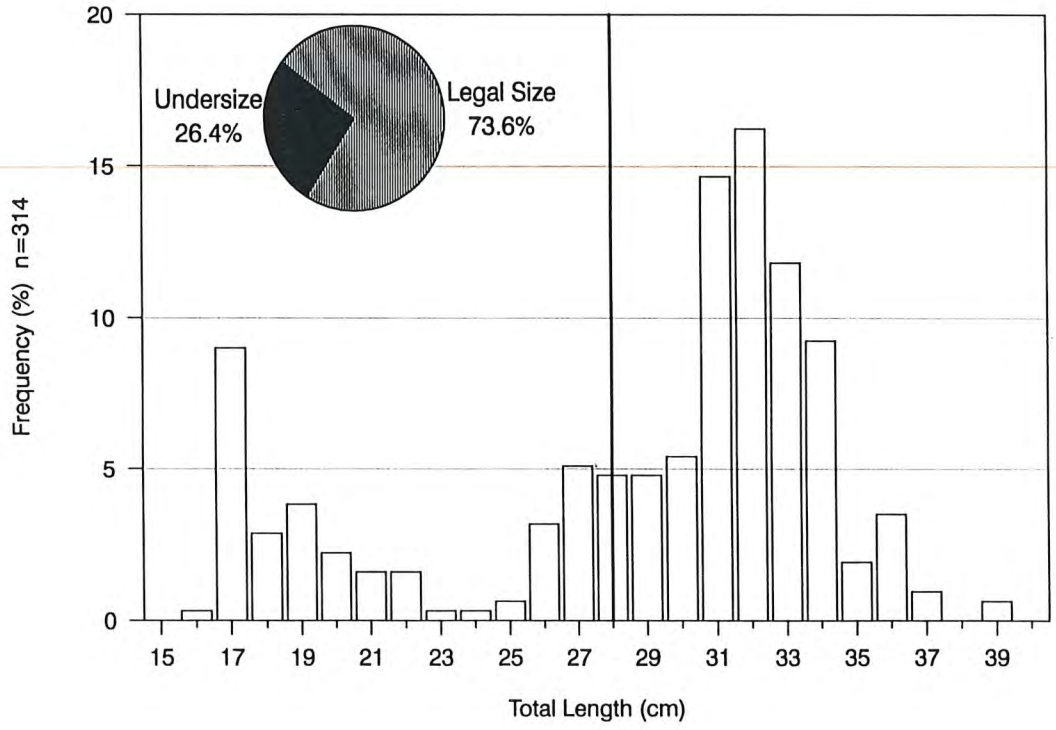


Fig 14 Size frequency distribution of King George whiting in recreational line fishing catch during Season 3

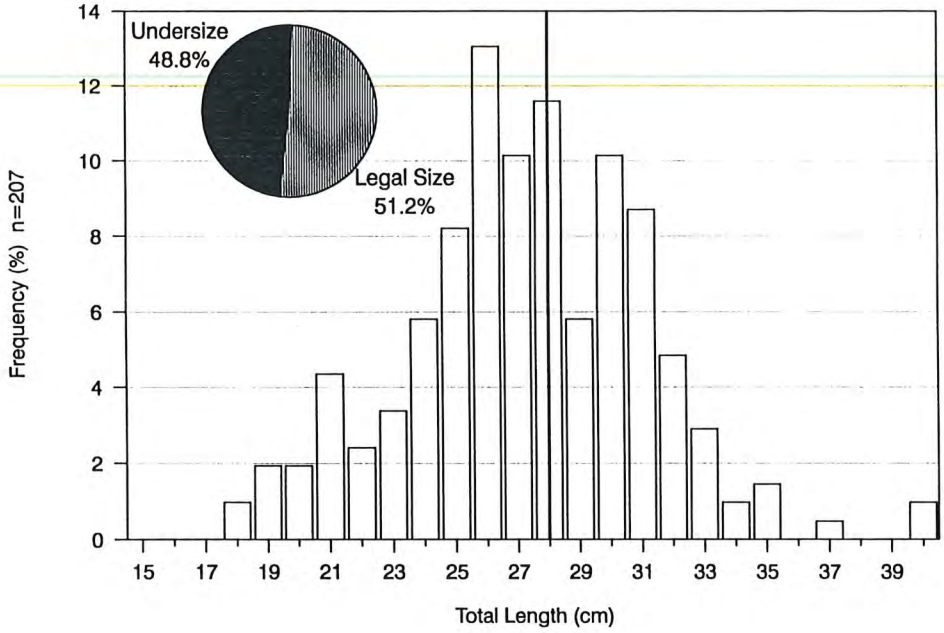
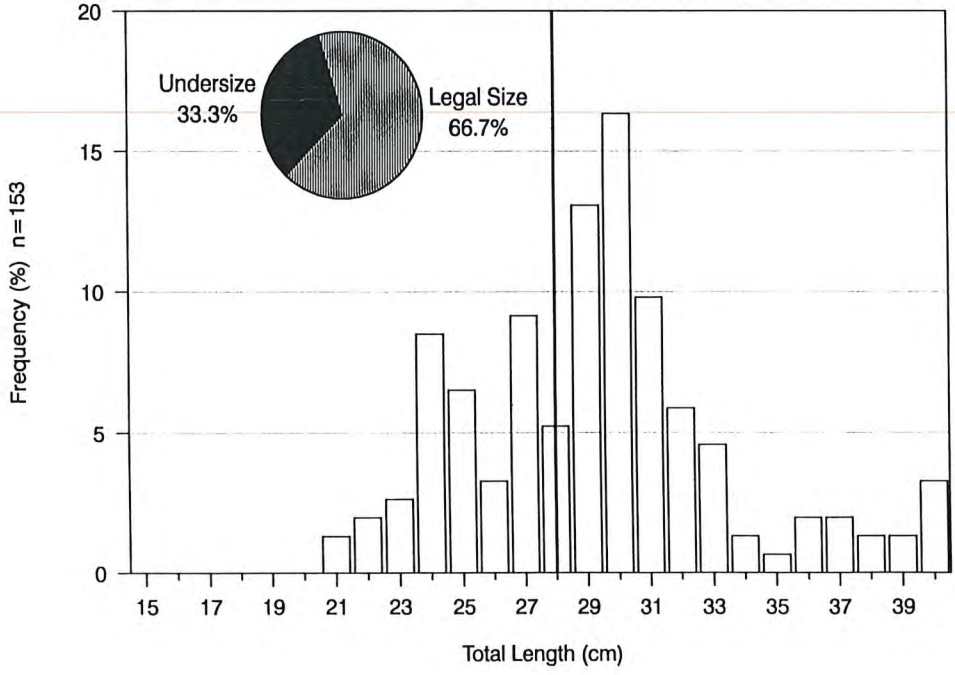


Fig 15 Size frequency distribution of King George whiting in recreational line fishing catch during Season 4



5.2 Impact of recreational hook and line fishing

5.2.1 *Undersize King George whiting number and effort in recreational line fishing.*

There is no regular monitoring program for recreational catch and effort statistics. However, during 1994, the SARDI Aquatic Sciences acquired FRDC funding to estimate the recreational catch and effort in both Gulf St Vincent and Spencer Gulf. The Gulf St Vincent survey was completed in April 1995, and the Spencer Gulf survey commenced at this time. Preliminary results of this survey estimated that a total of about 180,000 undersize King George whiting were caught in Gulf St Vincent from May 1994 to April 1995. Based on the two months (April and May of 1995) of survey in Spencer Gulf, and considering the trend from the preliminary results of Gulf St Vincent, it is estimated that recreational fishers may capture about 577,000 undersize King George whiting in Spencer Gulf in 1995.

5.2.2 *Size distribution and availability of undersize fish caught in the recreational line fishery*

The survey of the recreational line fishery was carried out mainly with the co-operation of recreational club fishers and other volunteers. Although season 2 produced 26.4% of the undersize fish, the results from the overall field observation clearly indicated that the recreational fishers had more probability of catching undersize fish than the haul net fishers (**figs. 12, 13, 14 & 15**). During Seasons 1 and 3, the undersize and legal size catch ratio by recreational line fishers was almost 1:1. However the recreational line sector caught a wide range of size groups starting from as small as 16cm to as large as 45cm. The 23 cm to 27cm size group dominated the undersize catch.

5.2.3 *Pre release mortality (PRRM)*

The pre-release mortality from recreational line fishing was found to be very low in comparison with the haulnet fishery. On average, the PRRM for undersize fish caught by recreational line fishers was 1.65% for 1994. In Season 1 (January to March) there was no PRRM observed during the sampling period and the PRRM in Season 4 was comparatively lower than in Season 2 or 3 (**fig-16 & table 6**). By applying the PRRM of 1.65% to the preliminary estimates of undersize King George whiting caught by recreational line fishers (See 5.2.1), the pre-release mortality was calculated at 12,491 fish.

Table-6 Recreational Line Fishing Mortality 1994

Seas-on	PRRM Surveyed Fishers				PORM Experiment		
	Boat Days	No. Fish	Mortality No.	Mortality %	No. of Fish	Mortality No.	Mortality %
1	20	123	0	0	59	0	0
2	17	82	2	2.44	54	0	0
3	13	108	3	2.78	64	3	4.69
4	12	51	1	1.96	62	0	0
Total	62	364	6	1.65	239	3	1.26

Fig 16 Pre release mortality in recreatonal line fishing

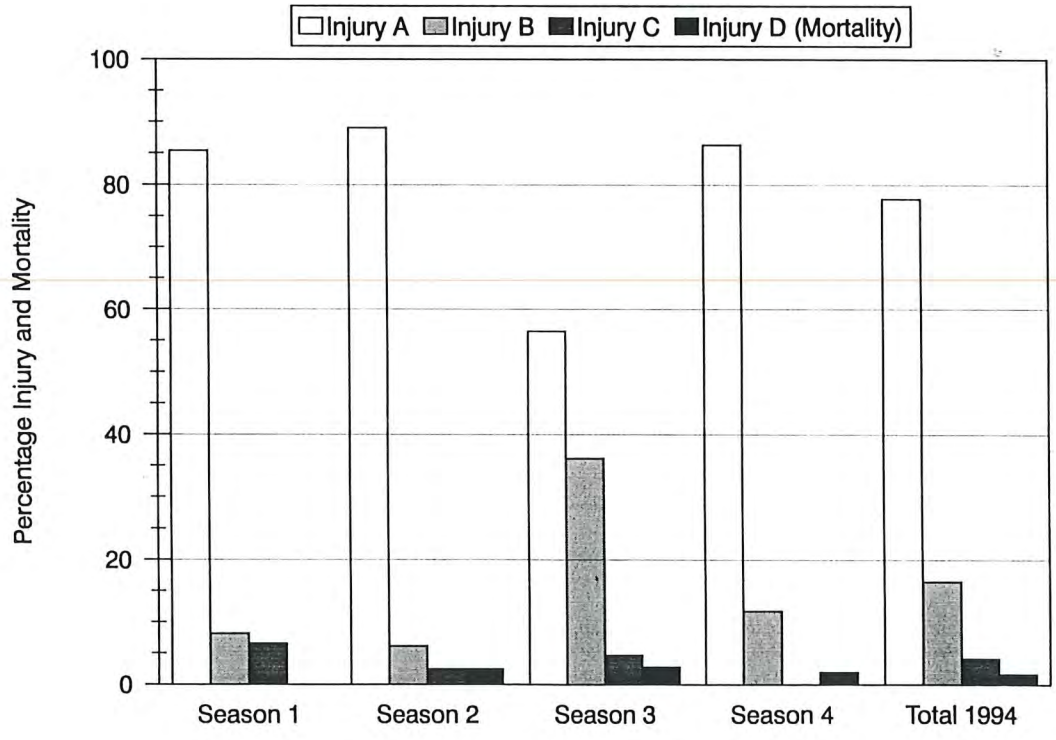
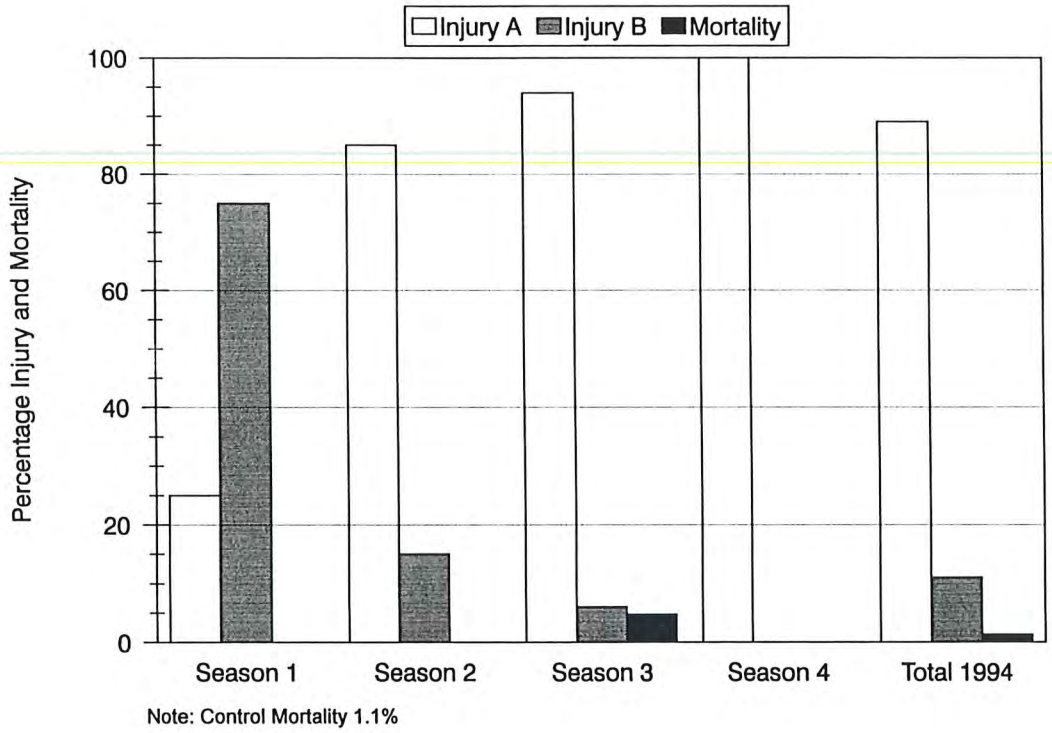


Fig 17 Post release mortality in recreational line fishing



5.2.4 *Injury status and post release mortality (PORM)*

* *Injuries caused during line fishing*

As explained in the methodology, the fish captured by hook were observed and the injury was classified according to the injury: (A) minor injury, hooked in the outer area of mouth with no observed damage; (B) fish hooked near eyes or gills, obvious bleeding; (C) fish hooked in stomach, difficult to extract and (D) mortalities. During the 62 boat days of field observation, 364 undersize fish captured by hook. Of these, 77.7% were classified injury A, 16.5% injury B, 4.1% injury C and 1.6% mortalities. Note that most of the hooking injuries were minor and did not appear to unduly effect the fish upon release.

* *Post release mortality*

Most fish caught by hook showed symptoms of stress in the form of fungal infections on the fins and changes in body colouration when held in experimental tanks. These fish seemed to feed and function normally and recovered during the course of the thirty day experimental period. One of the fish was observed to have actually swallowed the hook and had a length of fishing line extending past the mouth. This fish survived and appeared to feed and behave normally.

The PORM experiment results indicated that the survival rate of line caught fish was very high. There were no mortality observed during Season 1, 2, and 4. However, in Season 3, in which conditions were comparatively colder, a 4.7% mortality was recorded (**fig.16**). The tank conditions, except for the atmospheric conditions such as temperature and photo period, were kept uniform for all experiments. The major difference observed in the over-all conditions between seasons was the water temperature. Season 3 was colder than the other seasons with the water temperature ranging from 13°C to 17°C and this may be the cause for the higher mortality, especially in injured or stressed fish. Based on the experimental data, the average PORM was 1.3%. Using the preliminary estimates of the total number of undersize fish caught by the recreational line fishery (5.2.1),the post release mortality was calculated (after subtracting the control mortality) at 4031 fish.

5.3 Plasma cortisol concentrations

5.3.1 *Fish caught in haul net*

The mean plasma cortisol concentration increased from 325.24nmol/l immediately after capture to 398.12nmol/l at 90 minutes. There was some indication that the cortisol levels had begun to decline after 120 minutes. A significant reduction (70%) in cortisol level was observed after 24 hours (102.53nmol/l) and almost the same level was maintained at the 48 hour mark. Nevertheless, a sudden increase in cortisol level was recorded after 72 hours but then decreased to the lowest level of 39.86nmol/l by 96 hours (**Fig.18**). Comparing the mortality pattern during the experiment and cortisol levels, 70% of the mortality occurred with 24 hours after capture and 30% of the mortality was observed within the third day..

Fig 18 Plasma cortisol comcemtrations in (nmol/l) haulnet and recreational line caught fish

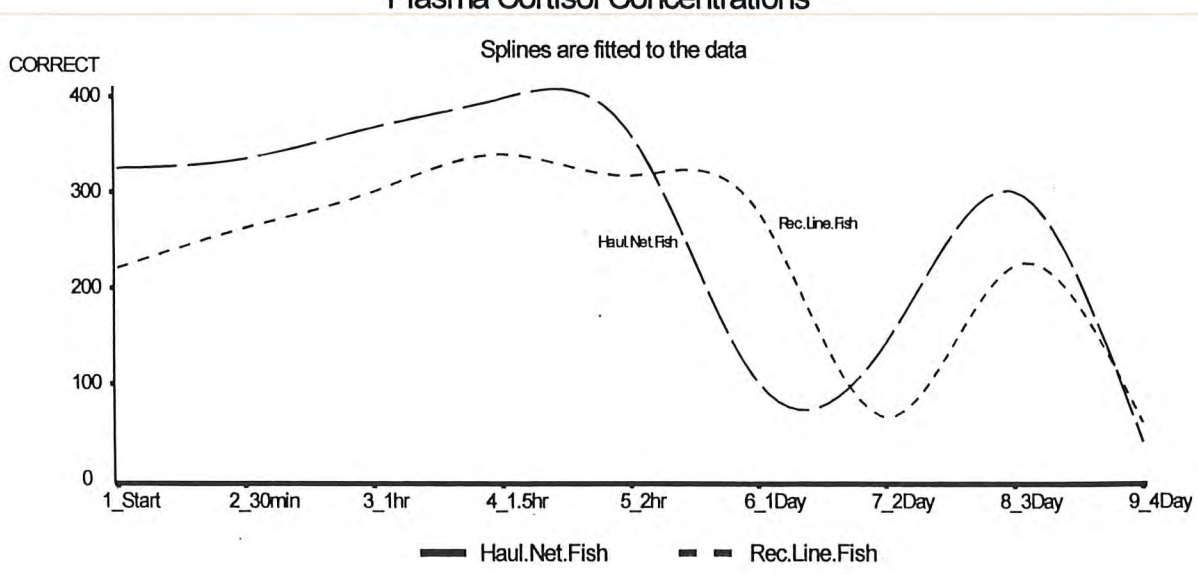


Fig 19 Difference in the level of cortisol concentration (nmol/l) after 24 hours
(The box indicates the middile half of the data and the line through the box marks the median value)

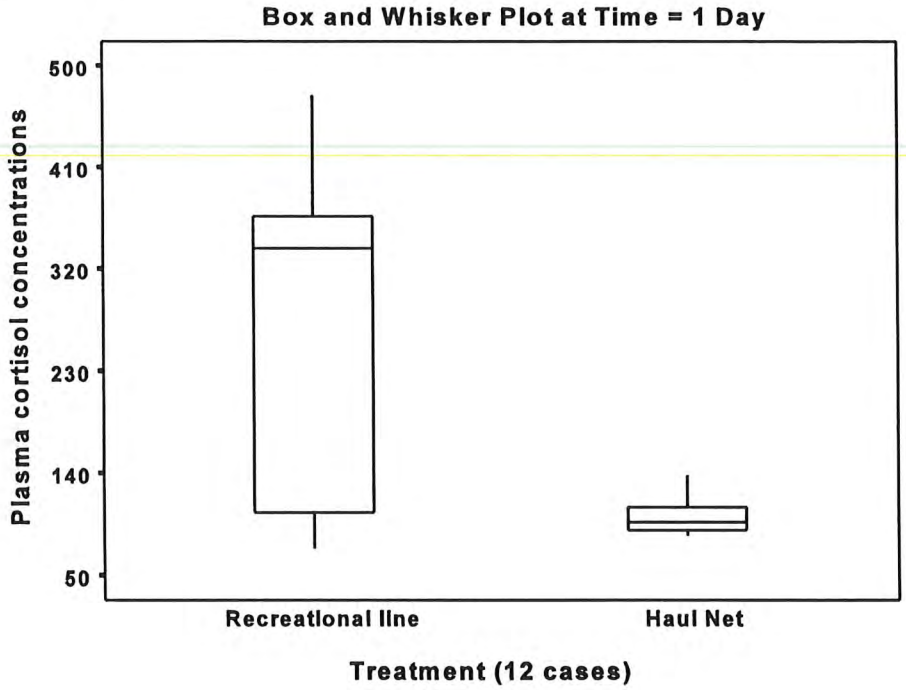


Fig 20 Difference in the level of cortisol concentration (nmol/l) after 48 hours
(The box indicated the middile half of the data and the line through the box marks the median value)

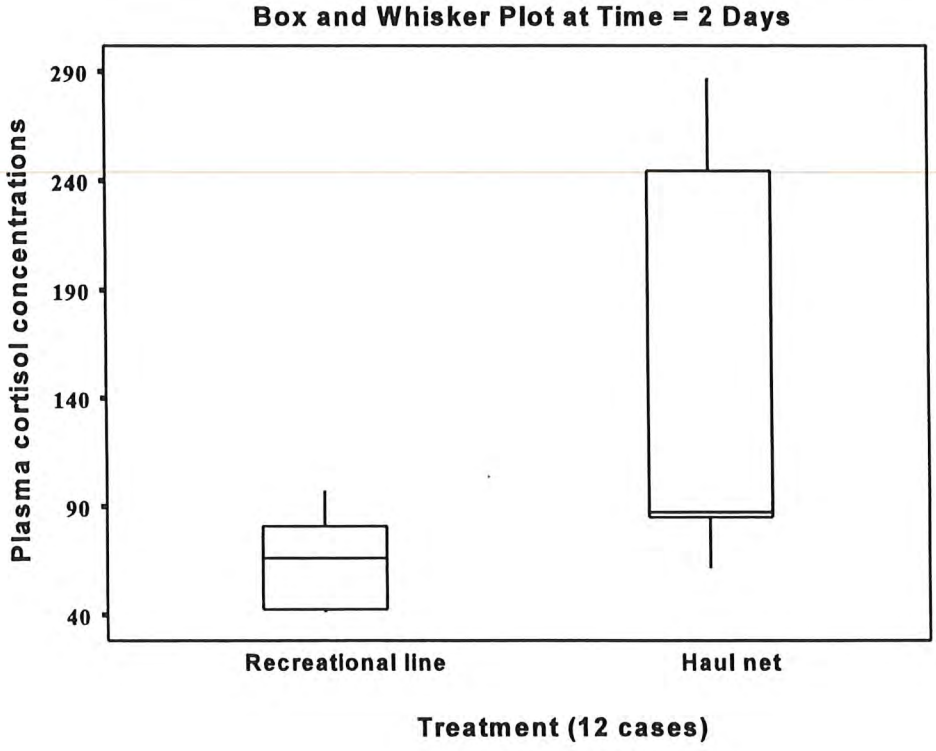


Table 6 One-way ANOVA for correct by treatment (haul net and recreational hook)

Time	Treatment	Mean nmol\l	Sample Size	Standard Deviation	F	P
0	Rec.line	221.27	6	90.143	2.61	0.1373
	Haul net	325.24	6	129.31		
	Total	273.25	12	111.46		
30 mins.	Rec. line	262.76	6	62.713	2.52	0.1434
	Haul net	335.01	6	92.133		
	Total	298.89	12	78.808		
60 mins.	Rec. line	300.68	6	97.229	1.15	0.3095
	Haul net	367.69	6	118.54		
	Total	334.19	12	108.41		
90 mins.	Rec. Line	339.70	6	131.72	0.54	0.4801
	Haul net	398.12	6	143.92		
	Total	368.91	12	137.96		
120 mins.	Rec. Line	317.80	6	112.74	0.41	0.5379
	Haul Net	362.80	6	127.92		
	Total	340.00	12	120.57		
24 hrs.	Rec.line	282.33	6	158.06	7.65	0.0199
	Haul net	102.53	6	19.349		
	Total	192.43	12	112.60		
48 hrs.	Rec. Line	65.624	6	22.106	3.53	0.0898
	Haul net	142.04	6	97.166		
	Total	103.83	12	70.462		
72 hrs.	Rec. Line	223.33	6	75.249	3.23	0.1024
	Haul net	301.75	6	75.840		
	Total	262.54	12	75.545		
96 hrs.	Rec. Line	60.130	6	27.542	1.74	0.2169
	Haul net	39.866	6	25.689		
	Total	49.998	12	26.632		

5.3.2 *Fish caught by recreational line*

The recorded plasma cortisol concentrations in fish captured by recreational line immediately after removing the fish from the hook were 221.27nmol/l and had increased to 339.70nmol/l at 90 minutes after capture. Unlike in the haulnet caught fish, the average cortisol level had declined considerably after 48 hours to 65.62nmol/l although, there was some indication that the cortisol levels had begun to decrease after 24 hours of capture. However, similarly to the haulnet fish, the average cortisol level increased markedly at the 72 hour mark and then decreased to the lowest level of 60.13nmol/l (**fig-18**). There was no mortality recorded after the first day (24h) of capture.

5.3.3 Statistical comparison of stress levels in fish caught by haul net and recreational line fish

Statistical comparison of stress levels in both haulnet and recreational line caught fish indicated (Fig 19, 20 and table 6) that the cortisol concentration significantly differed after 24 hrs of capture. Although, the stress level was markedly different during 48 hr mark, the variation was comparatively smaller than 24hr mark. Even though, the cortisol level in haulnet caught fish dropped significantly by 24 mark, after 48 hours the stress level was observed slightly higher than recreational line caught fish. This may be due to the difference in the type of stress the fish undergone during the capture.

6 DISCUSSION

6.1 Issues on regulations and policies which had a direct bearing on the number of undersize King George whiting caught by both commercial haulnet and recreational line fishing.

6.1.1 *The minimum legal size limit and haul net minimum mesh size.*

Lagler(1968) defined the size selectivity of a gear to be the portion of the total population of a certain size-class of fish which is caught and retained by a unit operation of fishing. Therefore, selectivity is the quantitative description of selection by a gear and is usually represented as the probability of capture of a certain size of fish in a certain-sized mesh. It is also obvious that when a mesh size is legally allowed, that particular gear should be able to catch legal size fish and allow undersize fish to escape. However, since this fishery is a multi-species fishery, the question at issue is: was the legal size limit (and consequent by-catch) of King George whiting considered when the 3cm minimum mesh size was set for garfish haul nets? The minimum mesh size for garfish haul nets was originally set in 1917 (as 1.25") and since then no alteration has been legislated, except for metric conversion to 3cm.

According to early historical records, the legal minimum size limit for King George whiting was originally fixed in 1888 at 5oz. Since then, the size limit has been converted to 11 inches and then to the metric measurement of 28 cm. All 3 limits refer to a fish of approximately the same size. The recently implemented changes (initially announced

by the Minister of Fisheries in May 1995) have increased the minimum size limit of King George whiting to 30cm and proposed a further increase to 32cm by 1st July 1998. When the legal minimum size limit was first fixed, the biological knowledge and stock status of the King George whiting was minimal. Currently available biological knowledge and stock status indications support the decision to increase the size limit.

6.1.2 *Promotion of netting during the period 1936-1959.*

The policy of promoting netting, whilst leading to the desired aims of diversification in the marine scalefish fishery and reducing effort on King George whiting, also introduced many more fishers to nets (open fishery policy) and without any restrictions on the species to be fished. This effort probably returned to King George whiting after a time and exacerbated the original problem.

6.1.3 *Increase in Fishing efficiency*

Improvements in fishing equipment and techniques have produced an increase in catches. There is no doubt that the absolute catching performance ratio of fish caught to the number actually present in the zone increased and the introduction of power hauling has resulted in the increase of catch per unit effort. This technical improvement has also enhanced the possibility of catching more undersize fish. Power hauling covers an equivalent area to approximately three ring shots and takes considerably more time is taken for each shot, which in turn increases the fish handling time. Fish handling time could be a possible factor impacting on undersize fish mortality, therefore, it is important to determine whether or not this technological change in fishing is contributing to the mortality. The present investigation will assist in determining this issue.

6.1.4 *Fishing participation*

The review of the history of fishing (Chapter 2) indicates that fishing participation increased at a rapid rate over the period of this review. From examining a century's fisheries management regulations, it seems clear that the administration focussed on managing the commercial fishing industry. At the same time, recreational participation swelled in accordance with the growth in population. Every recreational fisher has the potential to catch undersize fish. The regulations used to control the recreational fishing effort rely on the size of the fish taken and bag limits. From our investigation it was understood that very rarely the recreational fisher caught his/her bag limit. (McGlennon 1992). It is important to regulate both the commercial and the recreational fishing sectors to manage the fishery, including attempts to reduce the mortality of undersize fish.

6.2 Key factors which influence the impact of haul nets on the survival of undersize King George whiting.

The mortality rate of undersize King George whiting caught in haul nets and issues on fishing operation and gear are discussed in the following sections.

6.2.1 *Garfish haul net and selectivity properties*

The selectivity of the gear is governed by the interaction of the gear with the fish, which is dependant on the material, design, size of mesh and net together with the location, time and method of use. Selectivity is also dependent on the species composition of the fish association, length composition of the population, and biological state such as age, maturity and fat content etc. The 3cm mesh size was designed and regulated for the garfish fishery. The catch size frequency distribution indicated that the catch of garfish below the minimum legal length of 21cm was negligible. **(Fig-21).**

The minimum length of garfish selected by the garfish haulnet was 21cm. Nevertheless, the garfish haulnets mesh captured King George whiting as small as 16cm total length. This was mainly because of the difference in morphological structure between the species. The quantity of this inadvertent undersize whiting capture and their survival rate will determine if there is any need to reconsider the existing mesh size. As explained previously (section 5), various material used for making/patching a single net over a long period of time produced different selectivity properties which varied widely both within sections of a single net as well as among different fishers nets. Therefore, a larger size range of undersize King George whiting were vulnerable to meshing than if a uniform mesh size was used.

The usage of a wide range of ply size also influenced the nets capacity to mesh fish as well as the tangling of, and injury to, fish. It was observed that the lighter ply sizes of 8 to 12 were more likely to cause damage to the gills and skin of fish. Ply sizes of 15 and over rarely meshed fish. However, the heavier ply size net not only costs more to purchase but also is likely to require more boat power when fishing. There is a need to determine the optimum ply and mesh size to achieve a balance between fishing efficiency and reducing damage to undersize fish.

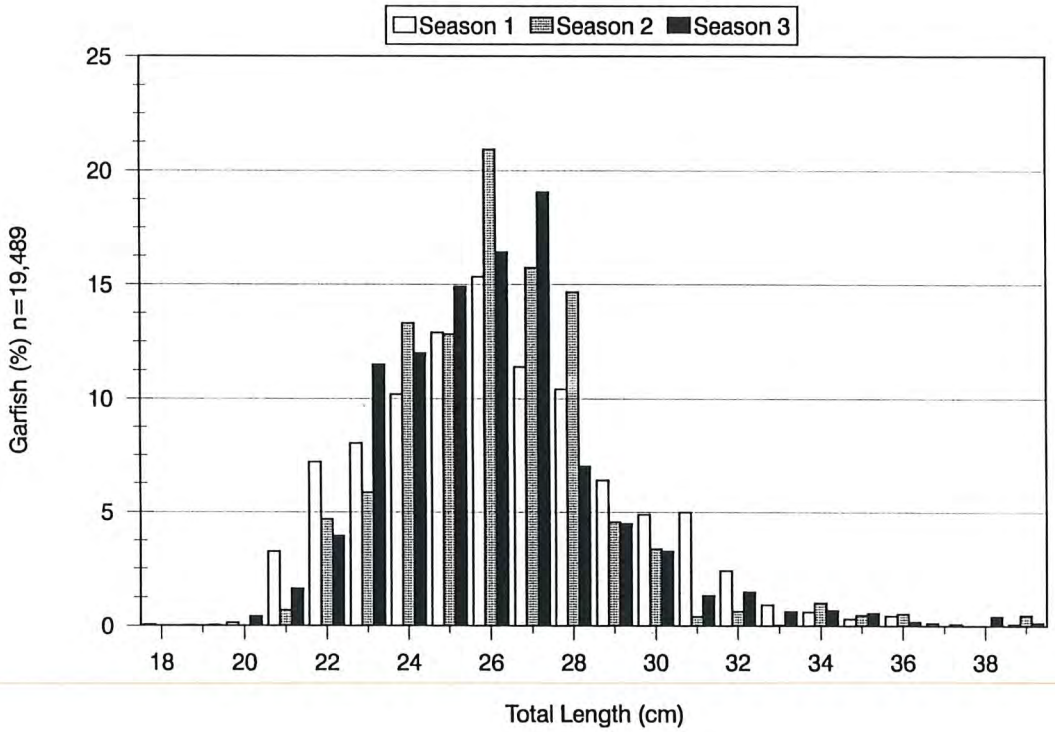
6.2.2 *Fishing pattern and effort distribution*

The fishers began the year with intensive use of the garfish haulnets, targeting garfish. During the first three months they applied 43% of the total effort of the year. During the rest of the year, fishers diverted a significant portion of their effort targeting other fish, such as King George whiting, using mesh nets . The time they have chosen for the relatively high effort on garfish did not produce any surplus catch. However, the size group of King George whiting which was most vulnerable to the garfish haulnets was found to be abundant during this period. As a result, 41.1% of the total undersize fish was caught during these three months and 70.5% of total pre-release mortality occurred during the same period. Catch statistics illustrated that the availability of

garfish was similar during all seasons except during November to December, when catches were low. Possible reasons for the high effort applied during season 1 may be:

* lack of legal size King George whiting;
* comfortable weather (summer) conditions for searching for garfish schools;
* a perception that garfish is predominant during this season;
* fishing habits developed through tradition.
* relatively high demand for garfish at this time of the year.

Fig 21 Size distribution of garfish in haul net fishery



This fishing pattern is questionable when compared to the availability of undersize King George whiting and their vulnerability to garfish haulnets at this time. There is a need to manage the high effort applied to garfish during January to March, without sacrificing catch. This would reduce the probability of catching undersize King George whiting and thereby increase the survival rate. The warmer period is the faster growing period for fish and any reduction in the effort at this time would allow the fish to grow and attain a comparatively larger size and possibly enhance the profitability to the fishers.

6.2.3 *Fish handling time and procedure*

Studies on other species, such as striped bass, indicated that lengthy handling periods could result in high mortality (Wydoski and Emery 1983). Dunning et.al.(1989) reported

that immediate mortality decreased from 16.1% to 1.2% for striped bass captured in seines and from 17.7% to 1% for striped bass captured in trawls when the handling procedure was modified. The average power hauling shot took about 2 hours to complete and during this time, fish are constantly being driven or chased. It would benefit undersize mortalities if this handling time could be reduced without sacrificing fishing efficiency. Power hauling techniques varied with the availability of fish. When fishers were unable to detect fish, they covered a larger area by shooting the net in a much larger arc and held the net open for longer periods. Such shots increased the handling time and may have reduced the survival rate of undersize fish. The fish handling time is directly proportional to stress which is directly proportional to mortality.

6.2.4 *Cause for undersize fish mortality*

The injuries caused by the net coupled with the stress due to the confinement, chase and drag of the netting action and predator attack were major factors contributing to the mortality of undersize fish.

a. *Netting injuries*

Net related injuries are the prime factors which cause mortalities. Several studies have shown that physical damage incurred during capture could result in significant increases in mortalities (refer 3.1.1). During this project, 27% of meshed fish died compared with a 7% mortality rate in pocket caught fish. Therefore, among the size group which are vulnerable to meshing in garfish haul nets , just over a quarter of them were likely to die if captured. This was also supported by 83% of mortalities (PRRM) coming from the 17 to 22cm size group **(Figs.22 & 23)**.

Fig 22 Size frequency distribution of King George whiting meshed in haul net

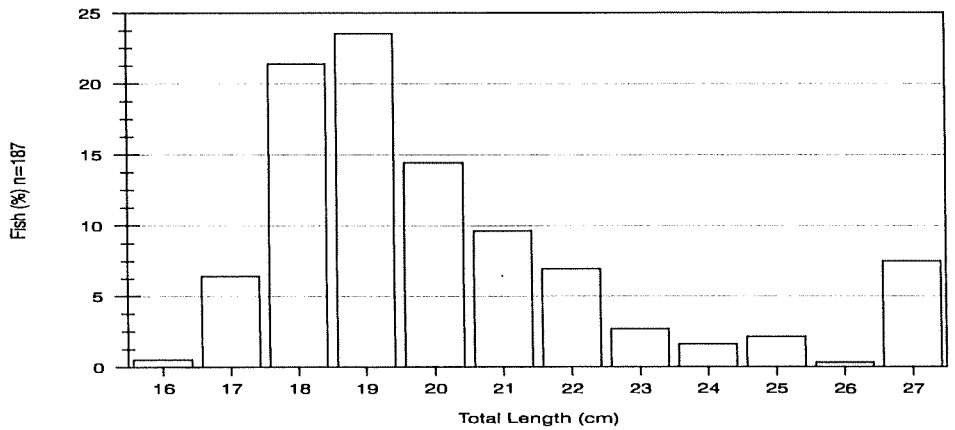
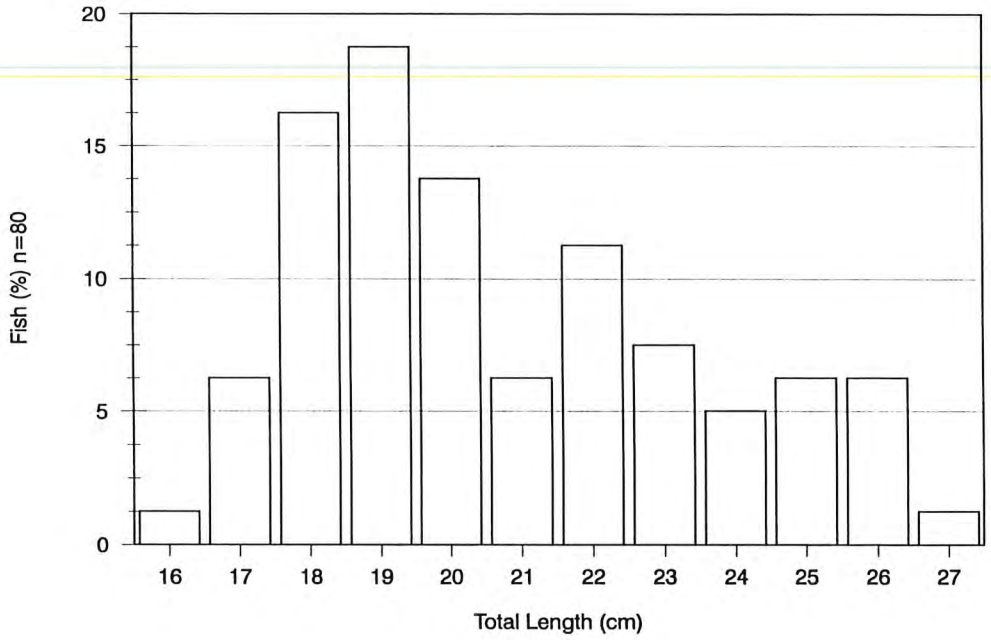


Fig 23 Size frequency distribution of King George whiting killed during haul net fishing



b. *Stress*

Various studies have shown that capture and confinement in fishing gear results in increased levels of stress (refer 3.4.1). During the Garfish haulnet operation, the stress could occur from several factors such as severe exercise, over-crowding and confinement. However, handling time has a direct influence on the level of stress.

The blood plasma analysis indicated that the fish caught in haul nets had the highest cortisol level compared with fish caught by hook and line or fish caught in a small mesh beach seine net. The reaction of a fish to a particular stressor will depend on the type of stressor, circumstances and severity (Wedeymeyer et al., 1990). Comparatively longer handling time, combined with netting injury, crowding and confinement may be possible reasons for the high level of cortisol concentration found in the blood plasma of fish caught in haul nets.

6.3 Possible ways of improving the survival of undersize fish caught in haul nets.

From the present investigation and various other studies (refer 3) , results show that netting damage and stress impacts from fishing are major causes of mortality. Therefore, altering the gear selectivity without reducing damage or stress incurred during capture may not be the most appropriate way of protecting undersize fish. Altering the mesh size/gear selectivity could be shifting the problem into another size group. Altering mesh size will not solve the undersize fish mortality unless the minimum selectivity of the gear is the same as the legal size limit for the fish. In a multi-species fishery, such as the South Australian Marine Scalefish Fishery, it is very difficult to regulate a mesh size which will be suitable for different species (eg.whiting and garfish). The results of this investigation could assist in resolving:

* Are there significant numbers of undersize King George whiting being captured and killed by the Garfish haulnet fishery such as to require a change in the gear regulations?

* Is there a need to improve Garfish haulnet fishing methods in order to reduce the number of undersize King George whiting mortalities?

On average, 10 undersize King George whiting were caught per boatday by the haulnet sector during 1994. Of this 1.5 fish were killed by the haulnet operation (PRRM) and 1 fish died after release (PORM),producing a total mortality was 2.5 fish per boat day. The average catch of legal size King George whiting (when targeting garfish) was 2.7 Kg per boatday. The total estimated number of undersize fish captured during 1994 was 23,967, of which 3,357 were PRRM and 2,062 PORM (calculated from laboratory conditions). Therefore, the total estimated mortality due to haulnet fishing during 1994 was calculated to be 5,419 undersize King George whiting. If these fish were to grow to the minimum legal length of 28cm (taking into account natural mortality, (based on Sluczanowski et al 1992), this would equal a live weight of 630Kg. This mortality is not significant compared to the commercial catch of 640,000Kg of King George whiting in 1994.

It may, however, be beneficial to attempt to reduce this mortality. Present investigations suggested two possible ways to improve the survival rate of undersize King George whiting. They are:

* reduce netting related injury; and
* reduce fish handling time.

The usage of heavier net ply size (15 and above) could reduce fish mortality by reducing the number of fish meshing and tangling and thereby reducing the severity of the injuries incurred. However, the economic and operational constraints due to heavier ply size would have to be considered.

A reduction in handling time could be achieved by adapting circular or semi-circular haul net shots. However, this alteration would reduce the area covered per shot and whether this sacrifice in area would make any significant difference in catch would need to be determined. Modification of fishing procedures to enable faster retrieval of the net and completion of the shot considerably quicker than current methods allow would reduce fish handling time. Normally the haulnet operation uses two crew members. Some fishers operate with a single crew on board and this increases handling time. It is essential for the fishers to understand a reduction in fish handling time will increase the survival rate of undersize fish.

6.4 Key factors which influence the impact of recreational line fishing on the survival of undersize King George whiting.

As a single fishing operation, the mortality inflicted by line fishing was significantly lower than that in the garfish haulnet fishery. Both PRRM (1.6%) and PORM (1.2%-including natural mortality) results strongly suggested that the undersize fish caught by hook had over 97% chance of survival. Therefore, the undersize fish caught can be returned to the water knowing that it has a very high probability of survival. Laboratory studies indicated that fish which swallowed the hook survived and initial indications were that the growth rate was not affected. Considering the high survival rate in the recreational fishery, there is little need to modify fishing practices when targeting King George whiting. However, the factors found to be influencing the overall mortality of King George whiting in this sector were:

6.4.1 *Regular increase in fishing participation and effort*

Due to both the population growth and the economic climate in South Australia, participation in recreational fishing has increased at a rapid rate. The mortality rate inflicted by recreational line fishing was found to be low, nevertheless, the larger numbers of recreational fishers results in a total mortality higher than estimated for the haulnet fishery. Therefore regulatory measures that will decrease the overall level of undersize fish mortalities may be required within the recreational sector in the future.

6.4.2 *Fishing characteristics*

The recreational catch size frequency distribution analysis did not reflect the general abundance of fish as recreational fishers do not necessarily use all available fishing time in the most cost effective manner. Frequently fishers travelled large distances in order to find larger fish or more scenic or calmer locations in which to fish. Many recreational fishers used fishing aids, such as GPS and echo sounders, to locate fish. Radio communication enabled even boats that did not possess fishing aids to readily use the information procured from boats with fish finding systems.

6.4.2 *Rate of undersize fish caught by recreational line returned*

Although it appears that only a small percentage of recreational fishers retain the undersize fish that they have caught, a small percentage in a huge recreational sector can make a lot of difference. There is a greater need for compliance to isolate the genuine recreational fishers from those who disregards the law.

6.4.3 *Targeting undersize fish*

There are areas where undersize King George whiting are found in abundance and recreational fishers fish these areas, knowingly or unknowingly. The ratio of undersize to legal size fish caught in these areas will be much higher than for areas where larger fish are predominant. These areas should be identified and consideration given to the introduction of fishing restrictions when undersize fish predominate.

7 CONCLUSION

Damage and stress impacted by fishing were the major causes of mortality. Factors such as rate of fishing participation, fish handling time, gear characteristics and fishing operational procedure influenced the rate of mortality.

Although haulnet fishing inflicted a high mortality rate, the total mortality was insignificant when extrapolated across the commercial King George whiting fishery, the major factors being low number of participants and a low proportion of King George whiting by-catch as the garfish haulnet mainly targeted garfish. By contrast, the mortality rate by the recreational fishers was considerably lower than for the haulnet sector. However, when extrapolated across a much larger number of participants, recreational line fishing accounted for a greater number of mortalities than the commercial haulnet fishing.

The recently introduced King George whiting size limit increase from 28 to 30cm and the proposed further increase to 32 cm by 1st June 1997 will have a positive effect on the King George whiting fishery because:

* the size group 28-32 are not vulnerable to garfish haulnets and therefore have a greater chance of survival if returned to the water.

* fish returned by the recreational line fishing sector have a 97% survival rate.

Another proposed change which requires net fishers to sort their catch whilst the pocket of the net remains in the water, is relevant to undersize survival. However, the time undersize fish remain in the pocket is also a major factor influencing the survival rate of fish upon release. Locating and returning the undersize fish to the water should be the priority of the fisher when removing the commercial catch from the net pocket.

The garfish haulnet, when used to target garfish, contributed about 1% (6.5tonnes) of the total (664 tonnes) 1993-1994 commercial catch of King George whiting. Therefore, the present study covers only a minor part of the total King George whiting fishery. The findings of this project suggest that the importance of investigations assessing the impact of technical developments on fishery resources have not been fully understood and should be given priority, along with fisheries economics, for future research. It is also essential for future studies to look at the impact of commercial line fishing and commercial gill/haul netting (using 5cm mesh) operations , targeting King George whiting, on the capture of undersize King George whiting and the impact of this on the resource. This becomes even more relevant with the new size limit as the 28 to 29cm size group, formerly legal size, will form part of the undersize catch of commercial gill nets and also commercial hook and line fishers.

8 RECOMMENDATIONS

8.1 A strategic plan should be developed to manage the use of 3cm net during the first three months of each calendar year in order to reduce the mortality of undersize fish without sacrificing significant commercial catches.

8.2 Better compliance with the haul net mesh size regulation must be promoted. A mesh size of less than 3cm should not be considered. An upper mesh size limit (say 3.1cm) would reduce the size group of King George whiting vulnerable to haul nets. Better compliance by the industry will improve the information available to the managers on the impact of nets on undersize fish.

8.3 In order to avoid meshing and tangling of undersize fish, a minimum ply size should be regulated. A study to determine the optimum ply size to avoid meshing and tangling and to understand the effect of ply size on the economics of fishing operations should be undertaken.

8.4 Fish handling time in the garfish haulnet fishery should be reduced. Furthermore, a study of haulnet fishing practises to improve the fishing methods without significantly effecting the economic viability of fishing should be undertaken.

8.5 A code of conduct on the sorting of catches should be determined. The return of undersize fish to the water should be a priority while removing the commercial catch from the net pocket. The duration in which the undersize fish remain confined in the pocket is one of the critical factors in determining the survival rate.

8.6 A study on the impact of 5cm net (gill/haul) and commercial line fish targeting King George whiting on the survival of undersize whiting should be undertaken. These sectors combined contribute more than 80% of the King George whiting commercial catch.

8.7 An education program highlighting to recreational line fishers that every undersize King George whiting they release has a maximum chance of survival should be implemented. However, it is recommended that the fishers should not deliberately catch undersize fish as even a small percentage of mortality inflicted by a huge recreational fishing sector could make a considerable difference in total undersize fish mortality.

8.8 Consideration be given to restricting fishing in areas where undersize fish are predominant. These areas should be identified.

8.9 In order to facilitates better management of the King George whiting resource, regular monitoring of the recreational fishery in addition to the commercial sector is essential.

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GLOSSARY

Garfish net:a haul net constructed of predominantly 3cm mesh,used mainly (but not limited to) to catch garfish.

Gill net (see Mesh Net)

Meshing:fish captured in a net by having one mesh of the net encircle them. The fish swim vigorously through he net ,stretching the twine. The net passes over the gill covers effectively acting as a noose capturing the fish.

Handling time: the time the fish are subjected to 'fishing stress'. In the case of net fishing ,this could be the time from when the shot wascommenced to completion of the fishing operation.

Haul net:a seine net designed and constructed to encircle fish used by either the power haul or ring shot method of fishing.

Haul net fishery: In South Australia, this fishery is a section of the Marine Scalefish Fishery with endorsements on their commercial fishing licences for the use of nets. The mesh size used usually ranges between 3cm and 5cm depending on the target species.

Mesh net: a net designed and constructed to enmesh (or 'gill') fish. This fishing method relies on the mesh size of the net matching the circumference of the targeted fish.

Mesh size: The distance from one corner of the mesh to the corner of the mesh diagonally opposite provided that the corners are extended so that as near as is practicable there id\s no space between adjacent threads. For legislative purposes in South Australia, this measurement is made after soaking the net in water for 5 min and then suspending a 1.5kg weight from one corner of the mesh. 10 meshes are then measured and the mesh size is the average of these measurements.(see *Fisheries Act 1982*, for details)

Ply size:the size of the cord used to construct the mesh.

Pocket: a section of the hauling net used for the final capture of the fish being surrounded, usually a 'V' shape and constructed of small mesh (3cm).

Power haul shot: a method of fishing in which a haul net is shot in a straight line or in a semi-circle and then hauled, by the boat, back to the point of commencement to form a circle and surround fish.

Ring shot: in this method of net fishing, the net is shot in a complete circle around the targeted fish, with no need to tow the net .

Wing: the section of a haul net designed to be towed. Sometimes of larger mesh size and usually of a lighter ply size and lighter construction.