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THE OVERFISHING OF THE EAST AUSTRALIAN TRAWL FISHERY

by

the late W. S. Fairbridge*

ABSTRACT

An account is given (drawn from two other, fuller papers by the author) of the history of the trawl fishery of the Austsralian east coast. Statistics of catch and fishing effort are presented and discussed with data bearing on the general biology of the principal species of the catch (the flathead, *Neoplatycephalus macrodon*) and dealing especially with the age composition of the catch. It is submitted that the evidence presents a convincing case of depletion caused by overfishing.

The substance of this talk is taken from two scientific papers, one of which was published in 1948, and the other is in press. The first paper dealt with the history of the east Australian trawl fishery and the gross catch statistics. The evidence there showed that the trawl fishery was at that time (in 1947) being overfished, and that the size of the fishing fleet would have to be cut by between a third and a quarter before there could be any chance of the fishery becoming stable.

The conclusions were drawn from the catch figures as a whole. These referred to a mixed catch of a number of species, and the catches of individual species were not shown. The more recent paper as yet unpublished, deals with the catch of what was the major species—the tiger flathead—a member of the family Platycephalidae.

In the present talk I shall follow the same line as that taken in the two papers, and describe first the overall history and catch figures of the trawl fishery; and then deal with the age-composition of the flathead catch, and the way in which the stock of this species has suffered under the overfishing.

HISTORY OF THE FISHERY

First, as to the location of the fishery; this is shown in Figure 1. It radiates, as it were, from Sydney, north and south. The narrow shelf, 15 miles wide, has rough bottom within 30 fathoms. There is a strong ocean current.

The furthest grounds are 350 miles south of Sydney. The steam trawlers land fish only at Sydney. The Danish seiners work from some dozen or more ports along the coast. They operate in a radius of about 20 miles from their particular port.

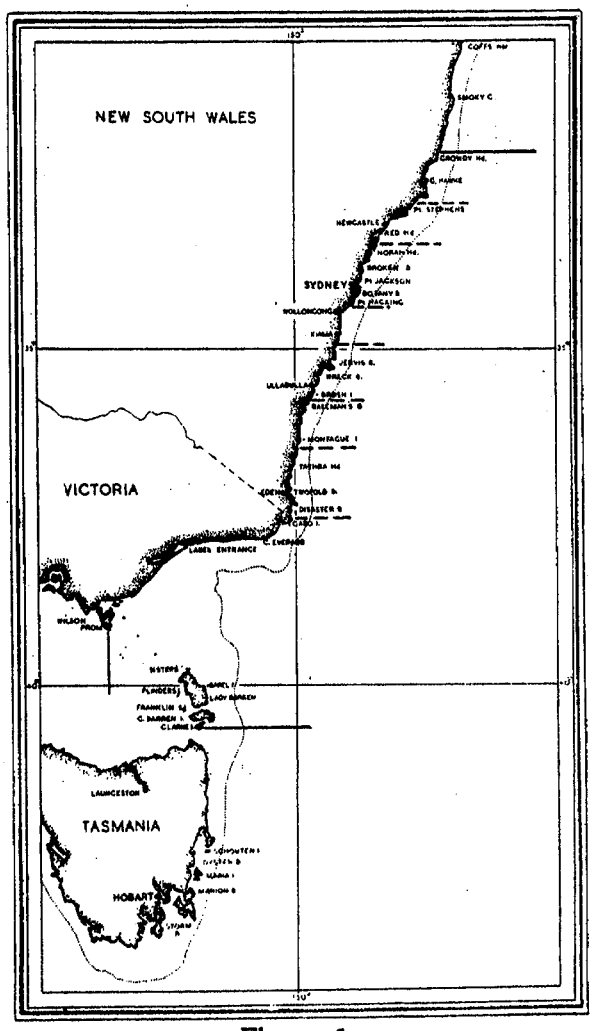

Figure 1.

Figure 2 illustrates the total trawl fish catch throughout the history of the fishery.

The top line is the total catch; the dotted line is the size of the trawling fleet. The lowest line represents, roughly, the catch per boat, obtained after expressing the Danish seiners and steam trawlers in comparable units.

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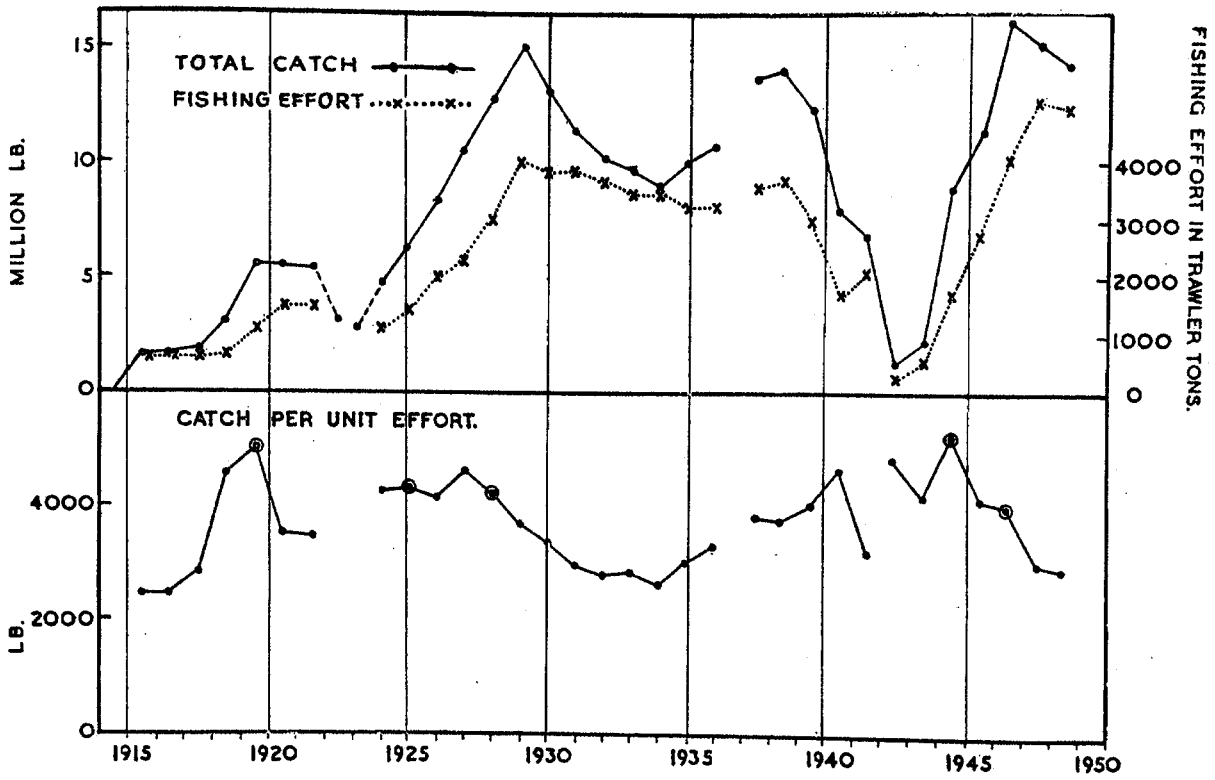

Figure 2.

The Australian trawl fishery had its beginnings in 1909 when H. C. Dannevig, of Norway, in the steam trawler "Endeavour" was commissioned by the Commonwealth Government to explore the trawling possibilities in this country. This exploratory work was carried on for five years, covering most parts of the eastern and southern seaboards of Australia, until the "Endeavour" was lost with all hands in 1914.

As a result of Dannevig's discoveries, the New South Wales State Government brought out some steam trawlers from England, and trawling was begun as a Government enterprise.

A start was made of trawling in 1915 with a fleet of 3 trawlers, which later was increased to 7. In 1922 business was handed over to private firms. More trawlers were brought out, and the catch rose to 15 million pounds in 1929. By the 'thirties the catch was falling, partly as a result of reduction in fleet, partly as a result of falling catch per boat.

By 1930 all the grounds that are now fished had been opened up. The falling catch per boat presumably was due to the heavy fishing. The catch per boat had been falling since 1927, although the total catch did not fall till after 1929.

But by 1935 the fleet had been reduced to 13 trawlers, and both the total catch and the catch per boat had begun to rise. I have therefore suggested that a fleet of this size is rather close to the desirable level. The catch at this time is not the theoretical optimum catch. But at this level of fishing intensity the catch was beginning once more to expand, and we may therefore regard the size of the fleet as a sort of *Empirical Optimum*.

However, about 1937 and 1938 Danish seining was introduced into these waters, and the fleet began to expand.

The catch, too, began to expand (though figures are suspect here), but the rate of catch suggests the beginning of a decline as one would expect if the fishery was indeed just beginning to recover from overfishing.

This point cannot be proved, because the war began to affect things in the year 1939/40, after which the size of the fleet and of the catch were falling, and the catch per boat rising.

The trawlers were being requisitioned during the war for mine-sweeping. In 1942, the very considerable fleet of Danish seiners was requisitioned for use in the war against the Japanese. This resulted

in a period of rest for the fish stocks. The extent of this rest may be expressed as two years of moderate catch, two years of very low catch, and then another year of moderate catch.

With the end of the war the trawling fleet began to increase; and in the flush of enterprise that followed the war, the total fishing effort reached a peak considerably higher than any hitherto. As was to be expected, the catch rose also to a peak—and then fell. The rate of catch, or the catch per boat began to fall almost immediately after the war; it has been falling now for four years, and is now about as low as it has ever been.

These results were felt at the time in 1948 to be quite expected, and typical of an overfished fishery.

That is the burden of the main conclusions that can be drawn from the gross catch statistics; but it is necessary to stress that these figures all relate to total catch: that is, to *all* the fish species taken by the trawlers. We now know that the gross figures are concealing some very interesting changes in the stock of what was the principal species—the flathead.

The rest of this talk is therefore more concerned with the fluctuating catch of the flathead.

BIOLOGY OF FLATHEAD

Our research into the biology of the flathead has taken the line, chiefly, of making an estimate of the age-composition of the commercial catch. This, indirectly, involves a complete study of the biology of the species. What follows, then, is a summary of the biology of the flathead, as it concerns the problem of age-determination—and then a brief account of the age-composition of the catch—and these results will be used to re-examine the catch figures.

The geographical range of the flathead is virtually contained within the heavy dark lines which mark off the limits of the trawl fishery. The species therefore occupies a narrow strip of coastline, bounded on the seaward side by the deep Pacific waters, and to north and south by what are apparently unfavourable conditions. The area of greatest natural concentration of the species is off Twofold Bay and perhaps extending up to Ulladulla. To the north and south of this area the flathead stock occurs in smaller concentrations and is less able to withstand heavy fishing. For some reason large numbers do not occur in Bass Strait to the west of Wilson's Promontory; only a few have been taken by trawlers working in that area. In Bass Strait trawling is confined to the eastern shelf.

Spawning is in this species protracted and occurs throughout the six summer months. The egg is planktonic. It has been obtained by artificial fertilization; but it has no markedly distinctive features, and it so closely resembles some other eggs to be found in the plankton in the same months that no work has been done on its distribution in the sea. Similarly, larvae belonging to members of the flathead family have been caught in numbers from time to time. But there are at least half a dozen closely related species occurring in the range of the tiger flathead, and it has not yet been possible to identify the larva of the tiger flathead with certainty.

We know that spawning occurs virtually throughout the entire area of distribution of the flathead, and bearing in mind the strong currents and counter-currents that sweep the New South Wales coast, there can be little doubt that the flathead larvae are distributed in varying numbers throughout the coastal waters, and that genetic uniformity is the rule throughout the flathead stock. It would be interesting to know what proportion of the eggs and larvae is swept out beyond the edge of the shelf and lost. It would seem that the numbers would be considerable. But as yet we have no knowledge about that.

We are next able to pick up the developing flathead at between 5 and 10 cm. in length. Experimental trawling using a finemeshed cover outside the codend has shown that the flathead of less than 3 years old are mostly to be found in the inshore waters of less than 30 or 35 fathoms' depth. We have taken them in numbers in 20 fathoms. But of grounds shallower than this I am afraid we can't say very much. The bottom is mostly rough inside the 30 fathom line, and it is difficult to find any place where one can use a trawl for sampling these younger age-groups. It may be significant that we found the greatest concentrations of these early age-groups in the Twofold Bay area—the area which carries the greatest number of adults. The important point is that this distribution of the young flathead largely places them out of the area of intensive trawling: Looking at it in another way, however, it may be that the intensive trawling kills off the young flathead which make bottom in the deeper water, so that the majority of the ones we found were inside this depth. The truth of this point could be demonstrated only by experimental closure of some of the trawling grounds—to see whether young flathead might begin to be found in the deeper waters under those conditions.

In their second summer the male flathead spawn for the first time, and the females mostly spawn for the first time in the year following.

The maximum size to which the flathead grows is sixty or sixty-five centimetres—but there are few specimens at this size, and to-day the majority are around 35 cm. The minimum legal length of this species is 33 cm. Hence quite a large proportion of

undersized fish is caught—about a quarter of those landed are under the legal size—mostly just under. The legal minimum size was established by the State Fisheries Department before much research had been done on the species, but we have no quarrel with it. A flathead of this size makes reasonable fillets, and it is in fact, about the size at which a high proportion of the flathead begin to be retained in the 3 inch codends. Most of the males have spawned once before reaching this size, and it is about the size at which the smallest females will begin to spawn for the first time.

Age determination

The otoliths have been found to be best for this purpose; but they are not good. It has been found that above a fish-length of 9 cm. the otolith grows in length in proportion to the fish. Length is measured from the centre to the posterior tip. The practice has therefore been made of measuring the intermediate lengths by means of an eye-piece micrometer. This was found to be a great aid in determining the true age of an otolith, in those cases where the record is confused by supernumerary annuli.

Supernumerary annuli are the great difficulty in interpreting these otoliths. The annulus is formed in midwinter. Spawning is in summer. It is not clear what actually causes translucent growth to be laid down in the otolith. But it does seem likely that the poor condition of the fish resulting from spawning during the summer may be an indirect cause of the formation of some of the supernumerary annuli. I have not been able to demonstrate to what extent growth may be correlated with the formation of opaque and translucent material in the otolith. In many fishes in which age-rings are clearly marked in the scales or otoliths, spawning runs into the period of slow winter growth: in the flathead, the two seasons are widely separated, and that may account for some of the irregularity in the annuli.

The otoliths figured in the plate must not be be taken as a fair sample. They have been selected for the clarity with which they show the rings.

The smallest shows no annulus, and the next shows one. The next shows two, and the next three—there is a very small band of opaque material on the very edge. This fish was caught in late June, so it had evidently formed its annulus a little early and had already begun to put on opaque growth. In the next, the innermost annulus cannot be made out clearly in the photograph, but there are three others outside it, making a total of four, with opaque growth on the edge. In the last there are four distinct annuli. The fish was taken in January, so its age would be exactly four years. In all otoliths the first zone of opaque growth represents an incomplete year—between 3 and 9 months.

One of the most important verifications of the validity of such age-determinations was that when we eventually obtained large samples of the smaller age-groups (by means of the experimental trawling), their length-frequencies clearly indicated the representative age-groups, and the modes of these age-groups agreed very closely with the actual calculated intermediate lengths which we had been obtaining for the past year or two, on theoretical grounds, from work on the otoliths.

Growth

From the calculated intermediate lengths obtained from the otoliths we have constructed some approximate average growth-curves.

The material was divided up according to sex and according to locality (Figure 3). It is seen

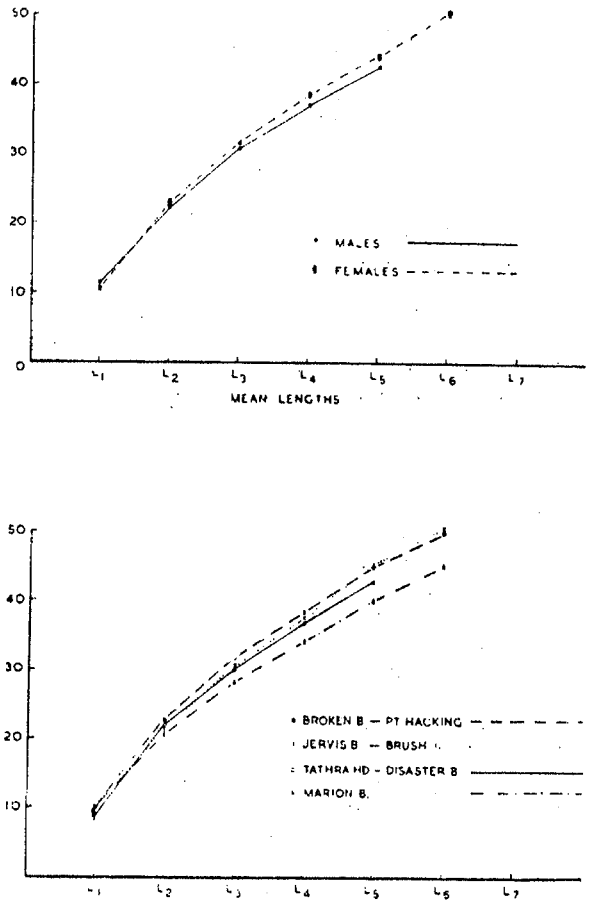

Figure 3. Growth rate of flathead. Ordinates show centimetres; abscisrsae show intermediate lengths.

that there is a small difference in growth-rate between the sexes. The males grow more slowly than the females. There are also locality differences. The fish from the northernmost localities grow fastest, and those from the south grow slowest. The curves have not been produced down to the origin, because the first increment does not represent a full year's growth.

AGE-COMPOSITION OF THE CATCH

The construction of an average growth-curve was not the primary objective in establishing a method for age-determination. What was aimed at was an analysis of the commercial catch into its constituent age-groups (Figure 4).

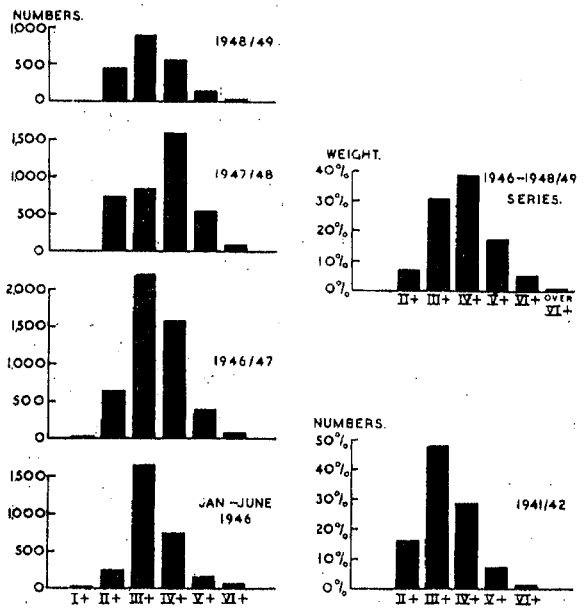

Figure 4.

Sampling of flathead is simplified by the fact that almost all the flathead catch is sold in the Sydney Fish Market. We therefore concentrated on random monthly length samples which were made representative of the whole commercial catch. From about one-tenth of these specimens we obtained otoliths. From the age-analysis of these otolith samples, we were able to weigh the random length samples, so as to get a good estimate of the proportions of each age-group in commercial catches. Since we know the size of the commercial catch in each month we can, from this, work out the actual weight of each age-group, or the actual numbers in each age group, in the commercial catch. The estimates of the catches for the four years on the left of this figure have been obtained in this way. The left hand axis gives the actual numbers of each age-group caught in each year—in millions of fish. The earlier year—1941/42—could not be treated in this way, and the numbers are shown as percentages.

It will be seen that the proportion in which the different age-groups occur is very regular. The III-group is the most important, followed by the IV-group. Only one year is aberrant—1947/48. In that year the IV-group is more important than the III-group. The annual reduction in numbers after the III-group is about 75 per cent, and it gradually increases with age. In the sixth histogram, on the upper right hand side, this material is averaged and the relative proportion of each age-group is expressed in terms of weight. In this case the IV-group is the most important, followed by the III-group.

The important features to notice in this series of histograms are, firstly, the virtual absence of fish over VI years old, and secondly the absence of violent year to year fluctuations in numbers of the different age-groups.

FISHING EFFORT

We can now turn to the actual catch figures for the flathead over the last few years (Table I). This table shows the catch of flathead and of the two other chief species, the morwong and nannygai.

It covers the latter part of the war, and the years since then. It is only during this period that statistics have been collected for individual fish species. And the results are quite startling.

In the first two years shown here there was little fishing effort. (The total fishing effort—in the right hand column—has been obtained by expressing the Danish seiners and steam trawlers in comparable units, and summing the two). The next year (1944/45) saw the maximum catch of flathead, and for the four following years the catch has declined. I want to stress that the actual total catch of flathead has declined, till it is now a little over one-third of the level of five years ago.

On the other hand, the trawlers have had to make up their catches with second and third quality species—the morwong and nannygai. These species were formerly not caught, or at any rate were landed only in very small numbers. The prices of these two species are approximately three-quarters and a half that of flathead.

It is seen that the catch of morwong rose to nearly 4 million pounds. Then it in turn declined in the last year. I repeat that these are actual catch figures, not rate of catch. Actually, the rate of catching of morwong is little more than half that of three years ago. It, too, is probably being overfished at present. Then, taking the nannygai, a

cheaper fish again, it is seen that the catch has risen to 5½ million pounds—it is now greater than that of either the morwong or flathead, and, in fact, the rate of catch is still rising. But it must be obvious that it is only a matter of time before the nannygai also will feel the effects of the heavy fishing.

Meanwhile, the effect of all this on the *total catch* is that there has been an overall reduction of 2 million pounds in the last 2 years.

It must be obvious from this table that we have here to do with a case of very severe overfishing. The fluctuations shown in this table cannot be due to natural population fluctuations—at least, not in the case of the flathead. This possibility was eliminated by the work on the age-composition of the catch.

Since the first paper on the trawl fishery was published (when the catch was still rising and was a record) two years' catch figures have become available; and it is clear that the catch of those two years amply supports the conclusions reached then—namely, *that the fishery was over-exploited, and that unless the fishing effort was reduced, the actual total catch would fall.* This prediction has come true.

But when we come to examine the flathead catch in the past, an even more remarkable and rather puzzling situation becomes apparent. I said that we had no catch figures for individual species in the early years. That is not strictly true. We have some series of old trawlers' logs covering three periods. Now these logs give the *catch of flathead*, and the *total catch* of the individual boats to which they refer. From this we can get the proportion of flathead in the catch of the individual boat. We appear to be on safe ground in assuming that this is much the same as the proportion of flathead in the catch of the whole fleet at the time. These figures are given in Table 2.

It is apparent that the proportion of flathead in the catch shows considerable regularity. Column 3 shows the number of boats from which the proportion was derived. The table has been continued down to recent years to make it complete.

In the early days more than 80 per cent. of the catches were flathead. In the next period (1928-1933) there was a steady reduction in the proportion of flathead from 95 to 65 per cent. This is the period of falling catch per unit effort. In column 4 I have calculated what the actual total flathead catch would have been on this basis, and in column 5 the rate of catch.

In the next period (1937/38-1941/42) the percentage of flathead was still falling, and so continued till the most recent period, until last year there was only 9 per cent of flathead in the catch. (These figures refer only to the steam trawlers, and do not include the Danish seiners).

The astonishing fact is that in the early days—1928, 1929, 1930—even after there had been considerable exploitation of the fishery, the actual (estimated) total flathead catch was between ten and thirteen million pounds. And to-day the total flathead catch is 2.1 million pounds. In the right hand column you have the calculated fall in the rate of catch as it applies to the steam trawlers. The figure to-day is less than one-tenth that of 1930.

What is one to make of a reduction of that magnitude? Can it be explained as merely overfishing?

Further, why was the postwar recovery of the flathead fishery not more pronounced?

This and other questions, which are dealt with in detail in a paper now in the press, can best be explained, I think, on the assumption that in this fishery the number of recruits is largely governed by the number of spawning adults. Hitherto, the reverse has usually been believed true of sea fisheries. As yet it can only be a hypothesis in this case. But I believe that we can explain along these lines the slow, or rather the halting recovery of the flathead stocks as a result of the war-time respite; and also, perhaps, this apparently cumulative effect of overfishing shown by the figures in this table.

The conservation measure which we are advocating, which we have been advocating for the past two or three years, is a reduction of the trawling fleet to about the level of 1935—the point at which the trawlfish stocks as a whole were beginning to show signs of recovery. As an additional measure, we advocate the complete closure of the Botany ground to fishing for an experimental period. That is the ground immediately south of Sydney Heads. It used to carry an enormous quantity of flathead, and flathead still do show up there in numbers at about spawning time. It is felt that this would be a most convenient and useful ground on which to study the effects of closure.

TABLE 1

THE CATCH (IN MILLION LB.) BY THE TRAWLING FLEETS, COMBINED.

	1. Flathead.	2. Morwong.	4. Nannygai.	5. Total Fish.	6. Total fishing effort expressed in thousands of trawler-ton-months.
1942/43.	0.5	0.02	0.1	1.3	4
1943/44.	1.2	0.02	0.05	2.2	6
1944/45.	5.7	0.5	0.1	8.9	20
1945/46.	5.2	2.0	0.8	11.3	34
1946/47.	5.0	3.9	2.0	16.2	50
1947/48.	3.8	3.9	3.5	15.1	57
1948/49.	2.1	3.0	5.5	14.2	57

TABLE 2

TRAWLERS' CATCH ONLY

1.	2. Proportion of flathead in the catch %	3. No. of vessels from which proportion was divided	4. Estimated total flathead catch: millions lb.	5. Catch of flathead per trawler-ton-month
1918/19.	88	7		
1919/20.	87	7		
1921/22.	82	7		
1922/23.	81	7		
1928.	95	1	12.2	367*
1929.	87	1	13.1	295*
1930.	80	1	10.5	243
1931.	80	1	9.1	224
1932.	76	1	7.8	201
1933.	65	1	6.3	174
1937/38.	65	14	7.5	180
1938/39.	62	5	7.2	174
1939/40.	68	8	5.8	204
1940/41.	59	4	2.3	218
1941/42.	41	3	0.9	123
			Actual flathead catch.	
1942/43.	41	1	0.5	157
1943/44.	47	1	0.5	237
1944/45.	38	1–4	0.7	95
1945/46.	29	4–5	1.2	92
1946/47.	22	6–11	1.9	74
1947/48.	19	12	1.9	60
1948/49.	9	12	0.9	25