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SUMMARY REVIEW OF A SCIENTIFIC SURVEY OF LAKE MACQUARIE BY C.S.I.R.O. DIVISION OF FISHERIES AND OCEANOGRAPHY

By J. M. Thomson

Marine Biological Laboratory
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FOREWORD

In a letter dated February 20, 1953, addressed to the Chief, C.S.I.R.O. Division of Fisheries, the Under Secretary of the New South Wales Chief Secretary's Department requested that the Division make "a complete scientific survey of a fishery like Lake Macquarie" because "there is evidence of serious depletion of stocks in the estuarine fisheries particularly in large lakes such as Tuggerah Lakes and Lake Macquarie."

The Division agreed to undertake a survey, and, although the allegations were of a condition of depletion, the officers concerned were aware that the symptom of a drop in catch could be caused by several factors other than depletion by overfishing, and therefore a full ecological survey was attempted.

The detailed evidence of the scientific studies on which this report is based will be published in a series of twelve papers in the Australian Journal of Marine and Freshwater Research. This report has been prepared at the request of the New South Wales Department and is designed to give a brief summary of the results discussed in those papers.

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SUMMARY REVIEW OF A SCIENTIFIC SURVEY OF LAKE MACQUARIE BY C.S.I.R.O. DIVISION OF FISHERIES AND OCEANOGRAPHY

By

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I. THE CHARACTERISTICS OF LAKE MACQUARIE

Lake Macquarie, lying immediately south of the City of Newcastle on the east coast of New South Wales, was formed since the last Ice Age by the incursion of the sea into a valley among the coastal hills. The original "entrance" was once much wider but the greater part has become blocked by sand deposition (the present Belmont flats). The outline of the lake is very irregular, there being some 25 bays and lagoons, providing a foreshore of 365 miles; although in area the lake is only a little over 42 square miles. The greatest length from north to south (Cockle Creek to Chain Valley Bay) is 13 miles: the maximum width west to east (Dora Creek to Galgabba) is 5½ miles (Fig. 1).

The lake is divided naturally into two portions by the projection of Wangi Point which is separated from the shallow Swansea flats by only a narrow channel. As a result the water movements in the two portions, whether tide-, wind-, or flood-induced, are almost completely independent except where they meet in the vicinity of the entrance channel, which is relatively narrow and is roughly L-shaped. Although there are deep gutters in the central portions there are shallow sand-bars at both seaward and lake ends of the channel. Examination of a series of charts dating from 1826 to 1954 shows that the area of the inner sand-bar has been increasing since 1864 when the first dredging occurred and the training walls and breakwaters were erected in 1884. As early as 1887 Sir John Goode, an expert engineer from England, commented adversely on these channel works and estimated that for the tidal flow to maintain sufficient scour to keep the channel free from siltation the channel should be no more than 200 feet between breakwaters. No attempt appears to have been made to follow this expert advice and continual dredging is necessary to keep the water at a reasonable depth over the two bars. The dredged channel into the lake was directed to the north of Pelican Island. The early charts show the natural channel to have been south of the island. During the years 1944 to 1957 when no dredging took place the dredged channel filled in and the natural channel was gradually re-establishing itself.

The effect of dredging and of removing shallows by enclosing the channel between rock walls has been to make the channel itself less attractive to fish. Bare sand does not contain many organisms used as fish food, and except for the side diversion into Black Ned's Bay there are 16,000 yards of mostly bare sand between the sea and the lake. The nature of the entrance channel also has another major effect on the lake. It is so narrow and shallow that the volume of water exchanged during a tidal cycle is only a small fraction of the volume of water in the lake. Measurements indicate that even if all the water entering the lake during the course of a flood tide were retained until all the original "lake water" was replaced it would take 100 tides to renew the lake's volume. This poor tidal ventilation results in a tidal range of three to four inches in the lake compared with three to four feet on the beaches outside. Despite this poor tidal exchange the lake is marine dominated over most of the year because the freshwater drainage is very slight, being provided by small creeks whose flow ceases during dry spells. It has been estimated that the annual inflow of freshwater is perhaps less than 10 per cent. of the volume of the lake. However, the discharge of freshwater into the lake during periods of prolonged rainfall has a profound effect on the lake, because of the narrow entrance channel which does not allow the rapid dispersion of the flood waters to sea. The freshwater entering the lake forms a layer on top of the normal salt water because it is less dense. Because of the shallow sand-bar at the inner end of the entrance channel the deeper salt water layers in the lake cannot pass to sea. When there is prolonged heavy rain it is some days, or even weeks, before the overlying freshwater layer can discharge through the entrance channel to the sea.

When a freshwater layer lies over a salt water layer there is practically no exchange of dissolved matter between them. This can be serious because salt water animals which cannot tolerate the freshwater, or which are attached and therefore cannot move to a more favourable position, must breathe and therefore keep on using up the oxygen dissolved in the water. When there is a freshwater layer between the salt water and the air, no new amounts of oxygen can dissolve in the salt water, and if the freshwater layer persists for any great length of time the oxygen in the salt water will fall to a level insufficient to keep at least some animals alive. Such periods of prolonged rainfall followed by stratification of the water and diminution of oxygen in the lower saline layer were observed in February 1955 and February 1956.

II. THE LAKE AS A FOOD PRODUCER

The carrying capacity of any body of water is limited by the amount of food it produces and the proportions of the various species of fish carried are determined largely by the relative amounts of the various foodstuffs required by the different species.

The two principal sources of food in any lake, river, or part of the sea are the plankton, which are usually microscopic drifting animals and plants floating in the water, and the benthos which is formed by the plants and animals attached to, crawling over, or burrowing into the bottom substrate. The plankton of Lake Macquarie, although about as dense as in the sea outside, is not extremely abundant; and in any case examination of the food preferences of the fish in Lake Macquarie shows very few which feed on plankton, and none of them is a commercial or angling species, though some of them are food for these. The greater number of fish species in Lake Macquarie depends upon the benthic food supplies. The lake bottom may be divided into three obvious zones. Firstly, there is an uppermost "weed zone" which extends from the shore to a depth of nine or ten feet. In this zone the sea-grasses and algae are dominant. In turn they provide both food and shelter for many smaller organisms. The nature of the bottom varies from rock and pebbles to sand with varying admixtures of mud, but in all cases the weeds are the dominant organisms in the food cycle.

Secondly, below the weed zone, in most places falling away to the deeps at an increased angle, is the "slope zone" which reaches depths of 20 to 30 feet. The larger sea-grasses are not found in this zone, the oval leafed _Halophila_ being the only one found and even that sparsely. Some rock is found in places but mostly the bottom is of fine sand grading in the deeper regions to a fine silt. In the weed zone free-wandering browsing animals are abundant, but on the slope these are absent and the dominant forms are attached or burrowing animals, which feed by filtering the water or by swallowing the surrounding silt to digest the particles of organic debris and microscopic organisms.

The third zone is the "mud zone," the almost flat bottom of the lake, which however does vary from a depth of 20 feet to 30 feet. The substrate here is a soft silt of jelly-like consistency, with a greasy looking surface provided by the accumulated faecal pellets of the aquatic animals. Because the mud zone is much deeper than the depth of the sand-bar at the inner end of the entrance channel, and because even heavy rain disperses as a shallow surface layer over the lake, the lake basin is never scoured out; and as the rate of flow of flood waters from the creeks to the entrance channel is very slow almost all the suspended solid material tends to settle in the lake, so that the silt layer is very deep. There are only two common animals in the mud zone and no plants. The animals are a brittle star, which was found in the stomachs of only one species of fish, the trumpeter whiting, and a burrowing worm which was found abundantly only in the stomachs of squire and occasionally in trumpeter whiting. So the mud zone is virtually a desert for most species, yet it forms 60 per cent. of the area of the lake bottom (Table 1).

TABLE 1

AREAS OF BOTTOM TYPES AND ESTIMATES OF THE WEIGHT OF INVERTEBRATE ANIMALS IN LAKE MACQUARIE

Zone	Area (Sq. miles)	Proportion (%)	Estimated weight (lb)
Weed	9.9	24	5,239,000
Slope	6.7	16	6,790,000
Mud	25.0	60	1,520,500

The weed zone, which includes 24 per cent. of the area of the lake, produces the most food. It does not carry quite so much weight of invertebrate animal life as does the slope zone (Table 1), but it produces an abundance of plant material which forms the basis of the food chain for the invertebrates and which is fed upon directly by herbivorous fishes of which three, sea mullet, luderick, and garfish, are commercially important species.

Though they also find food in the weed zone, black bream and flathead feed in the slope zone which is well stocked with invertebrates, but forms only 16 per cent. of the lake's area and therefore cannot support such a large population as the weed zone.

III. THE FISHES

One hundred and three species of fish were taken in Lake Macquarie during this investigation. Thirty-four are fishes of commerce although only 12 are of importance in the lake.

(a) Trends of Catch

The trends of the total catch are shown in Figure 2. At first examination it might appear that since 1922 there has been a depletionary trend. The catch has certainly dropped considerably since that time but the abundance of fish as measured by the catch per man has not fallen. From 1913 to 1936 the catch per man was lower than in the preceding 20 years, but from 1938 onwards it increased again. It might be said that the total catch fell because fewer men fished, not because fish became less abundant. It might be suggested that with fewer fishermen fishing, the catch per man should increase rather than stay the same; but the gear used by the fishermen has remained substantially the same over the years and would be expected to make catches of similar size if the fish numbers and density of distribution remained the same.

After 1922 the estuarine fishing industry was faced by competition from the rapidly growing trawler fishery. No other significant event has been recorded at this period to account for the lowered estuarine catches, and the competition from the trawlers was specifically blamed in the Annual Reports of the New South Wales Department of Fisheries in 1926, 1927, 1928, 1929. In addition the report of 1927 specifically stated that there was no diminution in the availability of fish to account for the drop in inshore fish catch.

The sudden fall in the number of men fishing after 1948 (Fig. 2) is due to the application of the 1947 State law restricting the issue of licences to full-time fishermen. The effect on the catch of these phases is shown in Figure 3.

(b) Catch Composition

The proportion of the more important species in the Lake Macquarie catch is indicated in Figure 4. Information on earlier periods is lacking. Sea mullet has been the dominant fish in the fishery, though varying from 24 per cent. in 1945 to 72.5 per cent. of the catch in 1954. In certain years leatherjackets have been plentiful, though they have been relatively unimportant since 1953. Tailor, luderick, and bream are well represented. Other species, which, in at least some years, provide an important portion of the catch are dusky flathead, river garfish, tarwhine, mulloway, snapper, and salmon. Data prior to 1954 include catches from outside the lake of which only leatherjackets form any great amount, and it may be that the occasional high catches of leatherjackets recorded before 1953 are actually from sea catches.

The catch per man of the important fishes is plotted in Figure 5. This indicates that there was a real drop in abundance of flathead, bream, whiting, luderick, and sea mullet between 1945 and 1947. The algal feeding luderick and sea mullet had recovered their abundance by 1951, but, apart from bream which showed a brief increase in 1955, the three ground fish had not regained their former abundance by 1957.

(c) Movements of Fish

The commercial fishes were tagged in order to trace their movements and to gain some idea of the intensity of fishing. Except for flattail mullet, which seem to move continuously about the lake, there was no evidence of any large interchange of fish between the northern and southern parts of the lake. This means that the abundant sea or poddy mullet population of the northern part of the lake remained largely unfished as relatively few are taken by anglers. It may be stated too that a failure by anglers to catch other species is not a good test of the presence of fish. It is a common experience for areas, which anglers have declared to be without fish, to yield a substantial catch to net fishermen. Movements within the portions of the lake are common for some species, but leatherjackets and squire seem to be largely sedentary in habit, remaining in the same small area except when the annual movement towards the entrance channel is taking place. This was shown by the recapture of many of these fish after periods varying from a few days to weeks and months still on the same spot where they were tagged.

(d) Repopulation of the Lake

The majority of the commercial species within the lake do not spawn there. Those that do, spawn mostly in or near the entrance channel. Tagging has given direct evidence that tarwhine, tailor, trevally, squire, leatherjackets, luderick, flattail mullet, and sea mullet move from the lake. Trapping near the entrance has shown at least sea mullet, bream, and estuarine perch moving in and out. The predominantly sea-inhabiting red gurnard, pennant-fish, nannygai, morwong, long tom, and jewfish certainly can be regarded only as visitors to the lake. It is probable that the population of most of the species is supplemented by movement of both young and older fish from other estuaries along the coast.

IV. THE STATE OF THE FISHERY

This investigation arose from allegations that the fish stocks were depleted. In fact it has been shown by study of the commercial fish statistics that although the abundance of all fish, as indicated by the catch per man, has not dropped to any marked degree, there was a real drop in the abundance of certain species during the period 1945-47 and that the recovery of these species was slow.

The drop in numbers of certain species has led to a hypothesis of depletion due to overfishing. However the evidence considered in this investigation suggests the drop may have been due to a change in the carrying capacity of the lake, following a catastrophic killing of certain items of fish food.

(a) A Hypothesis of Depletion

Although the term depletion is often used simply to indicate any drop in catch, in fisheries science the term is understood to imply a drop in catch due to a particular cause, namely, overfishing. A drop in catch in terms of weight (which is the method used in recording commercial fisheries) can result from one of two causes. (1) The same number of fish may be caught but the weight is less because the fish are caught at a lower average weight, or (2) there are fewer fish. The majority of estuarine fish are caught in the first year after they reach the legal minimum length and market sampling of the species affected in Lake Macquarie reveals no significant departure from the normal size distribution.

There was no sudden increase in the number of men fishing at this time to provide an overwhelming pressure on the stocks. It is true that in 1940-41 and 1941-42 the intensity of fishing increased so that the catch per man in the latter year reached its highest recorded value and the total catch was at its heaviest since 1923. It may be thought that this heavy predation may have reduced the numbers of young that would have entered the fishery in 1945.

In theory, over-fishing could result in fewer fish by the reduction of spawning stock with consequently fewer young being produced. In fact there are no unequivocal demonstrations that there is a direct relationship between the number of spawners and the number of consequent young surviving to fishable size. This is due to the fact that in most species fecundity is high, and the mortality rate is not uniform throughout life, nor is it necessarily independent of the density of the stock. If this resiliency to mortality did not exist, no fishery would last more than a few years after its inception, for the removal of even one fish would theoretically reduce the numbers of the next generation, and this would progress with every generation till none was left.

Apart from the fact that it would be a remarkable coincidence for four species of diverse fecundity, feeding, and breeding habits to reach the depletionary state simultaneously, this phenomenon could not be an isolated happening in Lake Macquarie, as there is a constant interchange of fish between the estuaries, proven beyond a doubt in the case of the sea mullet and indicated both by observation and by tagging in the case of other species. There is no evidence in the catch statistics of a coast-wide drop in catch of the species concerned at this period.

(b) <u>A Hypothesis of Catastrophe</u>

The hydrological evidence showed that in 1955 and in 1956 during autumn when heavy rain occurred over a prolonged period there was a marked stratification of the water, the freshwater runoff forming a layer over the normal saline water in which there was a marked reduction of oxygen. Examinations of the rainfall records show that there were at least four monthly periods since 1940 when the rainfall was either of greater amount or of greater daily intensity than in 1954-1956, the years when the investigation was being carried out (Fig. 6). A series of dry years preceded the heavy rain of 1946. It is suggested that upon some of these occasions of flood the oxygen content of the saline water may have been lowered to a level lethal for at least some species.

The abundant recently dead mollusc shells and the lack of large living molluscs other than a particular species of mussel which has been shown experimentally to have remarkable powers of withstanding bad conditions, indicates that such a catastrophe may have occurred. No reserve breeding populations of most of these molluscs were found in Lake Macquarie indicating that reseeding with young would have to take place by movement of plankton containing the larval molluscs through the entrance channel into the lake. Several species of mollusc which at first were not found alive gradually appeared as newly settled young. Presumably organisms other than molluscs, such as polychaet worms and algae, would have been affected but these leave no skeletal remains as evidence.

The rainy period in 1946 was a severe one, the mean daily fall being greater than at any other period recorded, although the total monthly falls for June 1950 and August 1952 were greater. Further heavy rains occurred in 1949 to be followed by other prolonged periods of heavy rainfall each year except 1953. These repeated periods of rain, providing conditions either lethal or at least detrimental to normal growth, would prevent rapid recolonization of the lake by planktonic larvae brought in from the sea by the tide. As a result of this loss of food organisms the fish-carrying capacity of the lake would be reduced.

Plants would be expected to recolonize more rapidly than animals and it may be significant that the two plant-feeding fish particularly affected recovered their abundance more rapidly than the carnivores.

In the absence of contemporaneous observations on the state of the benthic fauna and flora prior to, during, and after the periods of heavy rainfall no proof of this hypothesis is possible. It is however in accord with the facts recorded during this survey of Lake Macquarie. If, as we believe, this hypothesis is correct, it indicates that unless some means can be devised to drain more rapidly, at least the surface waters of the lake, the situation will recur whenever there are long periods of very heavy rain.

V. RECOMMENDATIONS

1. Consideration should be given to improving the drainage from the lake. This is an engineering problem on which this Laboratory is not competent to advise, but certain considerations are relevant. The area and volume of the lake are so much greater than that of the entrance channel that possibly immense works would be necessary to have any marked effect. Dredging on the scale of previous occasions would have little effect on this problem and would make the entrance channel unattractive to fish by providing a clear sandy channel and by increasing the area of sand flat at the inner end of the channel by natural transport of the waters. If dredging to allow boat traffic is resorted to, it is suggested that following the lines of the natural channel south of Pelican Island would lessen the rate of silting up compared with that previously experienced in the artificial channel cut to the north of the island.

2. The open waters of the northern part of the lake should be open to mesh netting from May to October each year. The number of anglers is small at this time of year and little interference with their sport would occur. As there is little or no interchange of fish between the northern and southern parts of the lake, these fish would otherwise be wasted as they are not efficiently fished by angling methods. Hauling nets are not recommended as many of the suitable hauling grounds are nursery areas which would not be disturbed by mesh netting.

3. The headwaters of all bays in the northern part of the lake and the waters of all lagoons around the lake should be closed to net fishing as these are nursery areas teeming with small fish. Specifically the following areas should be closed to all netting; Belmont Bay, Cockle Bay, north of a line from Marmong Point to Morse Street, Speer's Point; Fennell's Bay above the road bridge, Kilaben Bay above a line from Styles Point to Toronto Road, Wangi Wangi, above a line from Fishing Point to the pier at Wangi Wangi.

4. The channel waters, including Swan Bay and the Swansea flats as far as the present closure line, should be closed to net fishing to avoid interference with the movements of migrating fish.

5. Active steps should be taken to discourage the taking of undersized fish by both net fishermen and anglers. From casual observation it seems probable that anglers kill a greater number of undersized commercial fish than do net fishermen. The great majority of dead small fish left behind when fishermen's nets are emptied are silver bellies, a non-commercial species which is often mistaken for small bream by some anglers.

6. The emptying of hauling nets in the water rather than on the beaches should be enforced. Most fishermen already do this but on occasion, particularly on the western side of the lake, fishermen were observed to haul their bunts out of water. Small fish thrown back from the beach usually die or fall prey to birds.

7. Prawn trawling should not be permitted in the lake. Trawling is a more efficient method of taking prawns, but the prawn grounds extend into the areas where small squire are abundant. Lake Macquarie is a fine nursery ground for squire and trawling would undoubtedly have a deleterious effect on them.

8. Consideration should be given to the fact that there is a conflict of interests between the commercial fishermen on the one hand and the anglers and tourist trade on the other. The catch figures suggest that fish are just as abundant in Lake Macquarie today as they were 50 years ago, but there are now more restrictions resulting in fewer commercial fishermen and smaller areas open for them to fish. As a result the commercial catch is smaller and the market is deprived of fish which could be available from this lake. On the other hand the number of anglers has increased and will presumably continue to increase. Even if fish are as abundant as 50 years ago, there are now far more anglers for them to be shared among; and the fish are harried far more, not only by inexpert attempts to catch them but by the increasing movement of boats on the water and the increasing encroachment of settlements along the waterfronts.

In this conflict of interests Lake Macquarie is typical of the situation in many Australian estuaries today. The fact remains that until larger offshore fisheries are developed the estuarine catch forms a dominant part of the Australian fish catch, mullet alone accounting for about 10 per cent. of this catch. Any restriction on commercial fishing in favour of angling sport, deprives the market of fish. This amount would not be compensated for by the amateur catches, for angling is at best inefficient, and with some fish, particularly the commercially important sea mullet, ineffective. Angling fears that the more efficient fishing methods of net fishermen will wipe out a fishery are largely groundless as long as sound management policies are adopted. The fact that there is to some extent competition between anglers and commercial fishermen is a social problem not a scientific one. It is our opinion that the stocks in Lake Macquarie are in as sound a condition as the environment, particularly the food resources, will permit.

VI. APPENDIX

The scientific papers containing the evidence on which the statement in this review is based are listed below:

I. "General Introduction," by L.G.M. Baas Becking, J.M. Thomson, and E.J. Ferguson Wood.

II. "Hydrology," by R.S. Spencer.

III. "Characteristics of Water and Mud," by L.G.M. Baas Becking.

IV. "Bacterial and Fungal Studies," by E.J. Ferguson Wood.

V. "Chlorophyll Distribution in Lake Macquarie," by P.S. Davis.

VI. "Plant Communities and their Significance," by E.J. Ferguson Wood.

VII. "The Benthic Macrofauna of Lake Macquarie," by R.J. Macintyre.

VIII. "Trends of the Commercial Fish Catch of Lake Macquarie and Management of the Fishery," by J.M. Thomson.

IX. "The Fishes of Lake Macquarie and their Food," by J.M. Thomson.

X. "The Movements of Fish," by J.M. Thomson.

XI. "Estimation of Fish Populations," by J.M. Thomson.

XII. "Summary Review," by J.M. Thomson.

DIVISION OF FISHERIES AND OCEANOGRAPHY

REPORTS

1. Thomson, J.M. (1956).- Fluctuations in catch of yellow-eye mullet Aldrichetta forsteri (Cuvier and Valenciennes) (Mugilidae).

2. Nicholls, A.G. (1957).- The Tasmanian trout fishery. I. Sources of information and treatment of data. (For limited circulation: not available for exchange).

3. Nicholls, A.G. (1957).- The Tasmanian trout fishery. II. The fishery of the north west rivers. (For limited circulation: not available for exchange).

4. Chittleborough, R.G. (1957).- An analysis of recent catches of humpback whales from the stocks in Groups IV and V. Prepared for the International Commission on Whaling.

5. F.R.V. "Derwent Hunter" Scientific Reports of Cruises DH3/56, DH4/56, DH5/56.

6. Cowper, T.R., and Downie, R.J. (1957).- A line fishing survey of the fishes of the south-eastern Australian continental slope.

7. Davis, P.S. (1957).- A method for the determination of chlorophyll in sea-water.

8. Jitts, H.R. (1957).- The ^{14}C method for measuring CO_2 uptake in marine productivity studies.

9. Hamon, B.V. (1957).- Mean sea level variations on the east Australian coast.

10. Nicholls, A.G. (1957).- The Tasmanian trout fishery. III. Rivers of the north and east. (For limited circulation: not available for exchange).

11. Nicholls, A.G. (1957).- The population of a trout stream and the survival of released fish. (For limited circulation: not available for exchange).

12. F.R.V. "Derwent Hunter" Scientific Report of Cruise DH6/56.

13. Chau, Y.K. (1957).- The coastal circulation of New South Wales from drift card results 1953-56.

14. Kott, Patricia (1957).- Zooplankton of east Australian waters 1945-54.

15. F.R.V. "Derwent Hunter" Scientific Reports of Cruises DH1/57 - DH4/57.

16. Rochford, D.J. (1958).- The seasonal circulation of the surface water masses of the Tasman and Coral Seas.

17. Chittleborough, R.G. (1958).- Australian catches of humpback whales 1957. Prepared for the International Commission on Whaling.

18. Australian documents prepared for the Unesco Conference on the Oceanography of the Tasman and Coral Seas, held at Cronulla, August 9-14, 1958.

19. F.R.V. "Derwent Hunter" Scientific Reports of Cruises DH5/57, DH6/57, DH7/57, DH8/57.

20. F.R.V. "Derwent Hunter" Scientific Reports of Cruises DH9/57, DH10/57, DH11/57, DH12/57.

21. F.R.V. "Derwent Hunter" Scientific Reports of Cruises DH13/57, DH14/57, DH15/57, DH16/57.

22. Robins, J.P. (1959).- F.R.V. "Marelda" Scientific Report of Cruises July 1957 - May 1958.

23. Chittleborough, R.G. (1959).- Australian catches of humpback whales, 1958. Prepared for the International Commission on Whaling.

24. H.M.A. Ships "Queenborough" and "Quickmatch". Scientific Reports of Cruises in 1958.

25. H.M.A.S. "Warrego". Scientific Reports of Cruises 1957-58.

26. Thomson, J.M. (1959).- Summary review of a scientific survey of Lake Macquarie by C.S.I.R.O. Division of Fisheries and Oceanography.

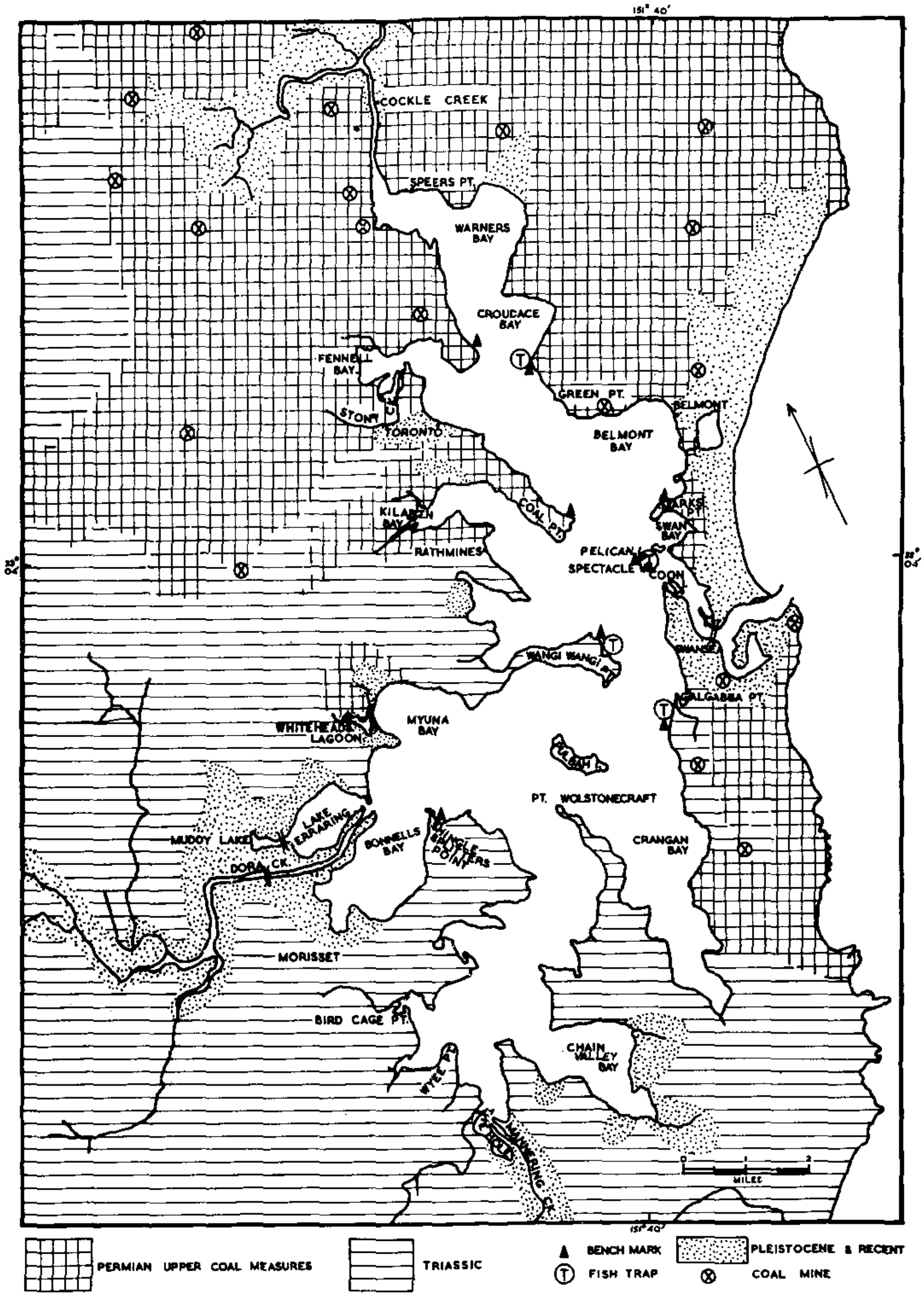

Fig.1. Map of Lake Macquarie.

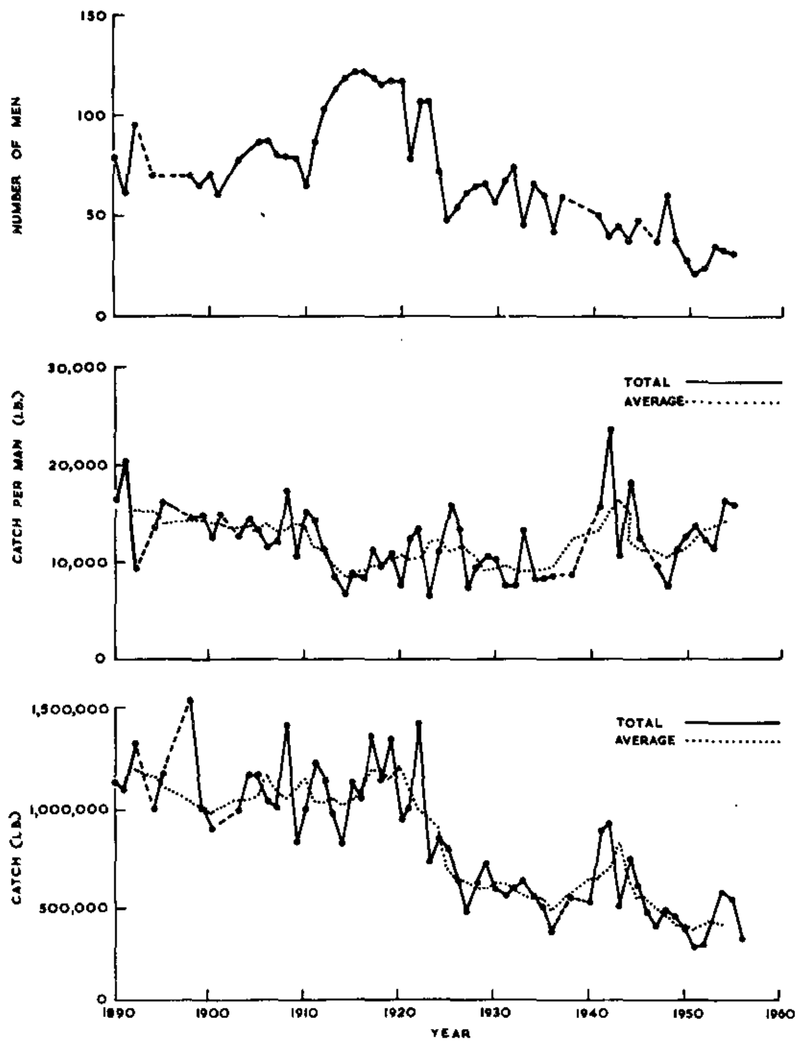

Fig.2. Total catch (bottom), catch per man (centre), and number of men (Lake Macquarie 1890-1956).

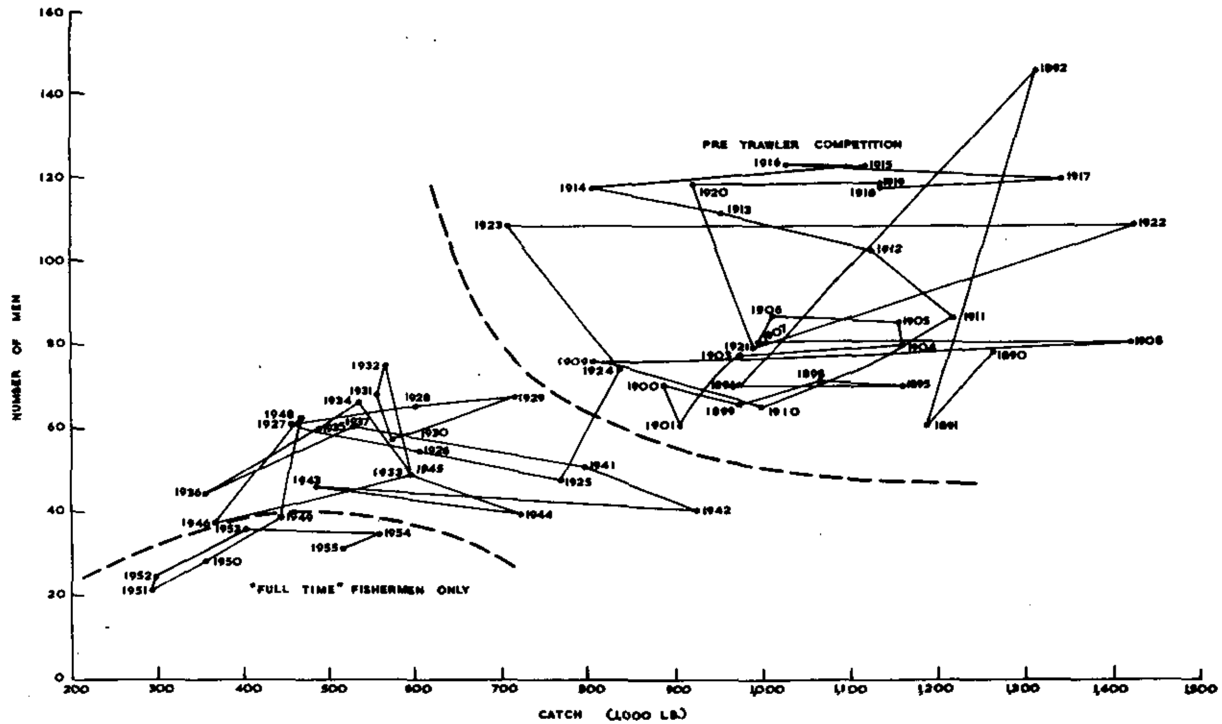

Fig.3. Relationship of catch to the number of men fishing, indicating three phases in the fishery - (a) 1890-1924, (b) 1925-1948, (c) 1949-1956.

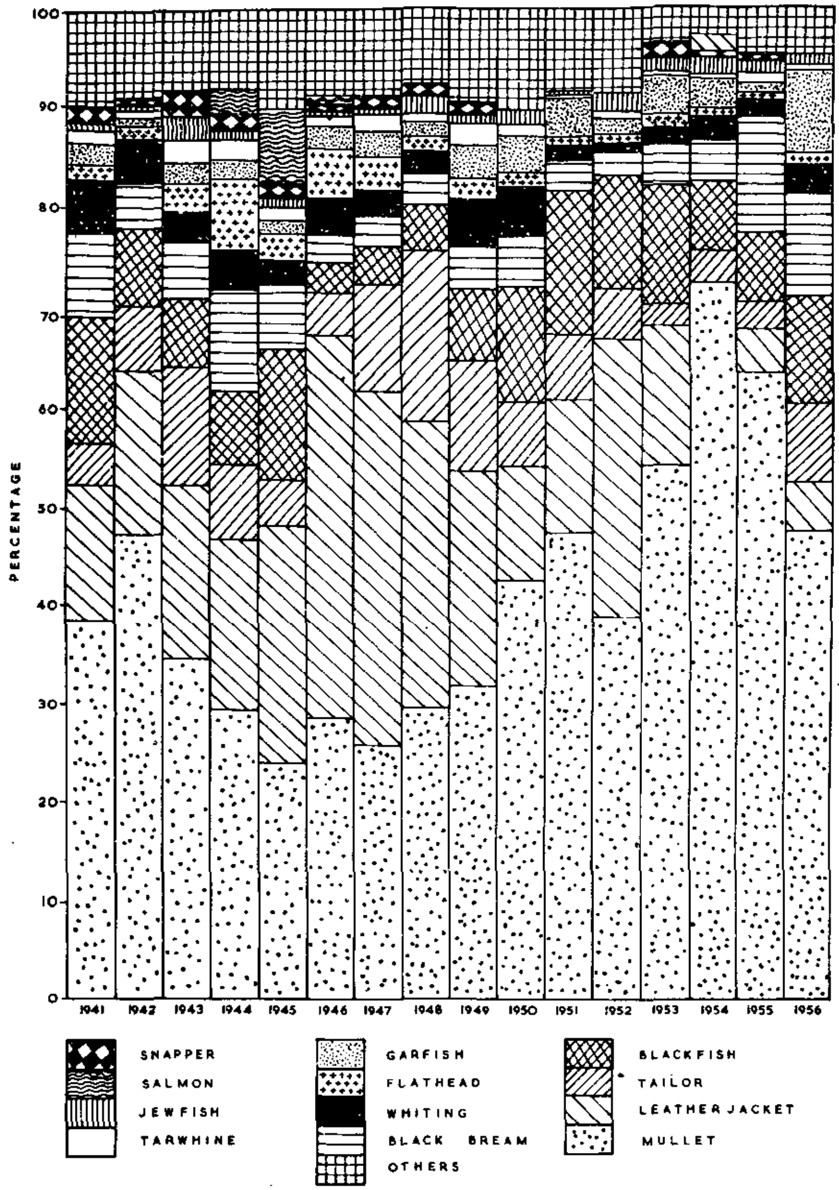

Fig.4. Catch composition, Lake Macquarie 1941-1956.

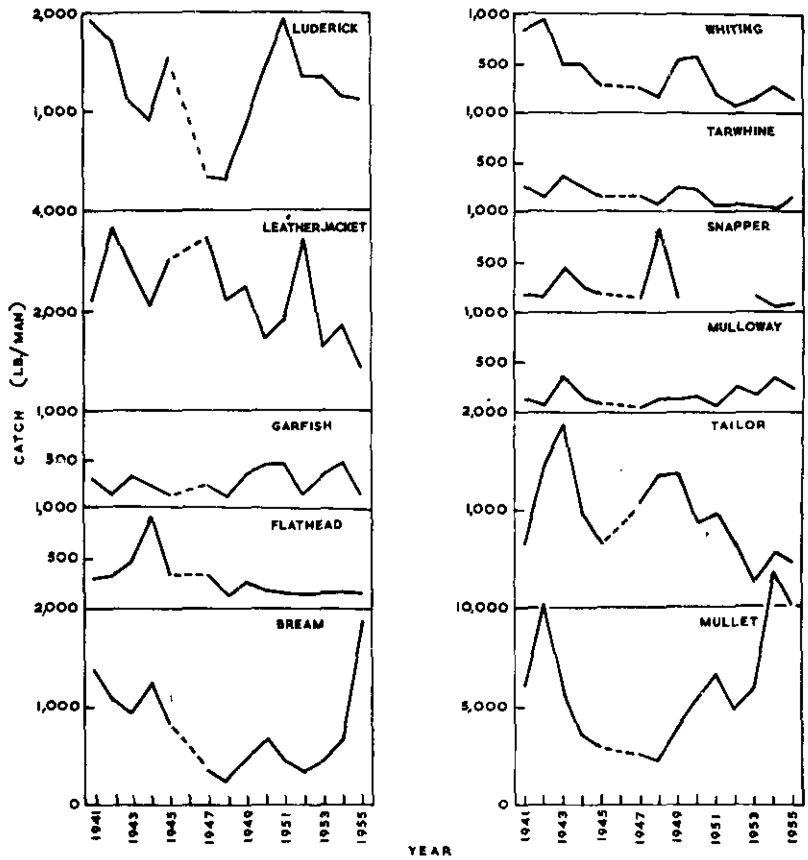

Fig.5. Catch per man of eleven commercial species Lake Macquarie 1941-1956.

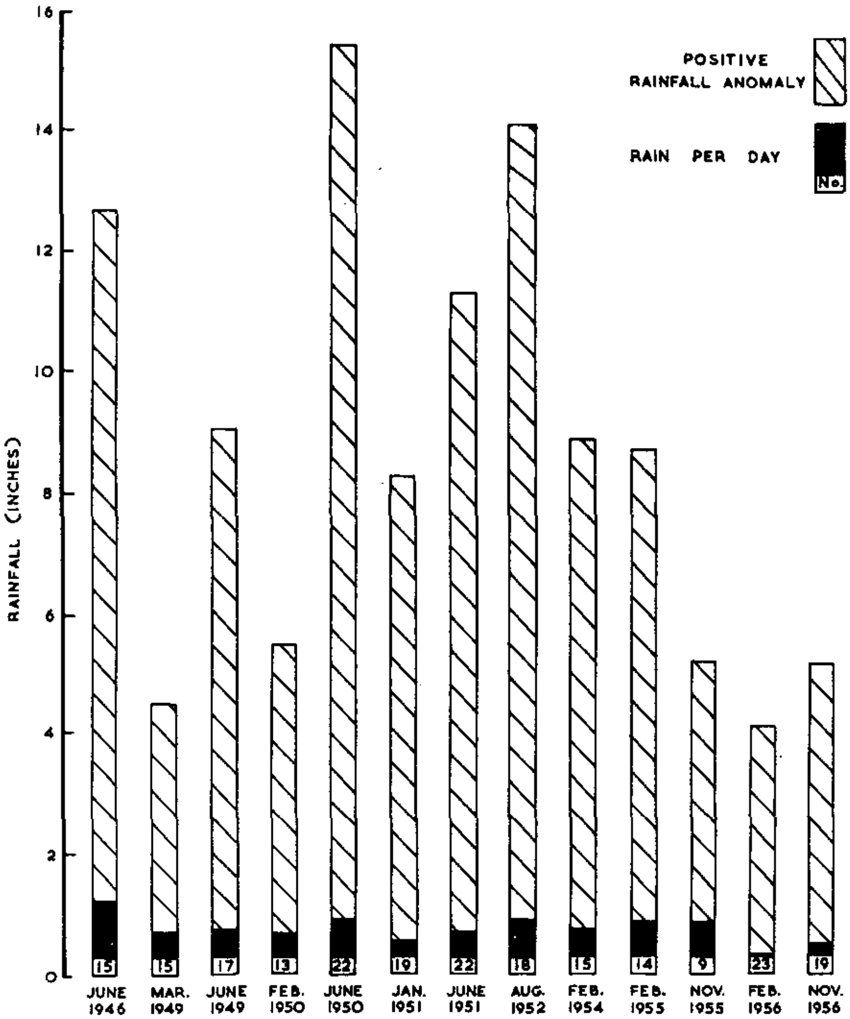

Fig. 6. Rainfalls greater than four inches above average recorded in any one month from 1946 to 1956 (hatched) with the intensity of fall as average fall per days rain. The figures below each column indicate the number of days in the month on which rain fell.