

FISHERIES

World Fishery

Sea mullet constitutes an important fishery in many parts of the world, mainly due to high stock accessibility and abundance. In 1998, 252221 t of mullet (Family: Mugilidae) was harvested from wild populations around the world (FAO 2000). This value included 25678 t of sea mullet, although total production by sea mullet fisheries was likely to have been considerably higher. In 1998, 36971 t of sea mullet was also produced by world aquaculture. Broad ecological tolerances, in combination with a generalist diet, also contribute to the widespread use of sea mullet in aquaculture.

Australian Fisheries

Sea mullet occur in waters of all Australian states. Commercial fisheries for sea mullet operate in NSW, Queensland, Western Australia, Victoria, Tasmania and South Australia. NSW production is greatest, followed by Queensland and Western Australia. Relatively small quantities are landed in Victoria, Tasmania and South Australia. It is likely that at least two stocks of sea mullet exist in Australian waters. Tagging studies have demonstrated that NSW and Queensland fisheries target the same stock, and it is possible that Victorian and Tasmanian fishers also target this 'eastern' stock. Western Australian fishers are likely to target a separate 'western' stock, which may also occur in South Australia.

NSW Fishery – History and Management

History and overview

Sea mullet was a highly significant source of fresh fish in NSW during the early days of European settlement. At the start of the 20th century, this species "was the staple product on the Municipal market, for the prime reason that it was most abundant" (NSW Fisheries, 1929). The commencement of the NSW offshore trawl fishery, in approximately 1915, reduced the market for sea mullet. Trawlers were able to supply the Sydney market with large volumes of high quality product (mainly flathead initially) at regular intervals. Sea mullet was more difficult to supply and was a comparatively low quality product. Individual inshore fishers caught relatively small quantities, had poorer handling practices, and faced greater distances to market (which also caused deterioration of product). Landings of various trawled species (e.g. flathead, eastern gemfish) have temporarily exceeded those of sea mullet, but catch rates of these species have fluctuated and in some cases have been unsustainable. In contrast, sea mullet landings have remained relatively high throughout the history of commercial fishing in NSW.

In 1999/00, sea mullet landings were the highest (2413 t) of all species taken by NSW fishers. By comparison, in the same year the second highest finfish landings in NSW waters were of school whiting (786 t).

Sea mullet is currently targeted within estuaries and along ocean beaches in NSW. Most of the catch is taken during the autumn/winter pre-spawning period, when adults are either aggregating in the lower reaches of estuaries or migrating along ocean beaches. Mullet are caught in smaller quantities within estuaries at other times of the year. Fish are targeted as a food fish, or as bait, for domestic and export markets. Females are targeted in winter to supply a valuable export market for roe. Relatively few sea mullet are taken by recreational fishers in NSW.

Management of NSW Ocean Hauling Restricted Fishery

The primary targets of the NSW Ocean Hauling Fishery are pre-spawning aggregations of sea mullet. These fish are mainly caught in 'general purpose hauling nets', which are beach seine nets that may be up to 400 m long, with an additional 400 m of hauling lines at either end. They consist of 50-65 mm mesh in the bunt, and 65-86 mm mesh in the wings. Small boats are used to deploy the haul nets and to encircle fish. Nets are typically hauled manually to the beach.

In March 1995, access to the Ocean Hauling Fishery was limited to fishers who could demonstrate historical participation in the fishery. After this time, new entrants were required to purchase existing entitlements. This measure was designed to prevent increases in effort within the fishery. In 1995, eligible fishers were allocated either a class A (skipper) or Class B (crew) endorsement to operate within the fishery, based on their history of participation in the fishery. Crew are not entitled to hold net authorisations, and must operate in the presence of a skipper. Any number of skippers and crew may work together as a team to target sea mullet. In 1998/99, there were 203 skipper endorsements and 207 crew endorsements within the Ocean Hauling Fishery. Approximately 180 skippers were entitled to use a general purpose hauling net endorsement, 89 of whom reported landings of sea mullet during 1998/99.

Ocean haul fishers are restricted to operate within one of 7 NSW ocean regions. The size of each region is dependent on the number of fishers it contains. For example, Region 2 (Clarence River) is small but contains a relatively high density of fishers. Hauling operations are also restricted by weekend closures of some beaches in summer, and permanent beach closures in some areas. Each restriction is designed to minimise conflict among fishers, and between fishers and local communities.

Management of NSW Estuary General Restricted Fishery

Sea mullet are also a major target species in the NSW Estuary General Fishery, and are caught in estuaries using 'general purpose hauling nets' and 'mesh nets' (gill nets). Hauling nets are mostly used to catch sea mullet during winter. A standard estuary hauling net is 375 m in length, excluding hauling lines. Wings consist of 80 mm mesh, while the bunt consists of 30-50 mm mesh at the centre and >50mm mesh in the remainder. However, there are many variations on allowable fishing gear among estuaries. Within some estuaries, hauling nets may be up to 1000 m in length. Various temporal and spatial haul net fishing closures apply within estuaries.

Mesh nets are used in estuaries to target sea mullet throughout the year. A standard meshing net is 725 m in length, with a mesh size of 80 mm or more. As with hauling nets, there are variations on allowable fishing gear among estuaries, and mesh nets may be up to 1450 m in some estuaries. At certain times/locations, fishers are allowed to use 'splashing' in conjunction with net deployment. Special permits to set nets overnight are issued in most regions. Temporal and spatial closures of mesh net fishing occur but are highly variable among estuaries. Many mesh net fishers opt to use a larger mesh size (e.g. 100 mm) to select female sea mullet during winter.

In March 1997, access to the NSW estuary fishery was limited to fishers who could demonstrate historical participation in the fishery. After this time, new entrants were required to purchase existing entitlements. This measure was designed to prevent increases in effort within the fishery. In 1997, eligible fishers were allocated an endorsement to operate within the fishery, based on their history of participation with each gear type. In 1998/99, 202 estuary fishers owned hauling net endorsements, of which 147 recorded landings of sea mullet during the year. In 1998/99, 778 fishers owned mesh net endorsements, of which 437 recorded landings of sea mullet. In total, 502 estuary fishers caught sea mullet in 1998/99, irrespective of method.

NSW Fishery – Catch and Effort

Total NSW catch

Early fisheries records from NSW waters are limited, and so early landings of sea mullet are difficult to quantify. Incomplete records exist from 1892 to 1922. After 1922, total fish production was reported from all NSW regions but details of individual species are limited. After 1939, separate listings were made for many important species. Difficulties in interpreting historical catch records arise due to changes in the unit of catch. Prior to 1922, the unit of catch was the 'basket' which contained approximately 84 lb of fish. After 1922, a 'box' of approximately 70 lb was used. Until 1942, fish were sold by these approximate units and not by weight (Thomson 1953). After 1942, estimates of total landings are considered reasonably reliable.

Between 1940 and 1980, sea mullet landings were relatively stable (Fig. 9). The vast majority of sea mullet were caught in estuaries during this period. Production in NSW increased gradually after 1980, and peaked at 5508 t in 1993/94 (Fig. 9). Production then remained above 4000 t until 1998/99, when annual landings fell dramatically to 2905 t. Trends in total catch since 1980 largely reflect fluctuations in oceanic landings. In contrast to oceanic landings, estuarine landings were relatively stable until the late 1990's.

In 1999/00, total annual landings in NSW were 2413 t, which was the lowest value since 1984/85 (Fig. 9). Contributing to this total was the lowest oceanic catch since 1987/88, and the lowest estuarine catch since 1956/57.

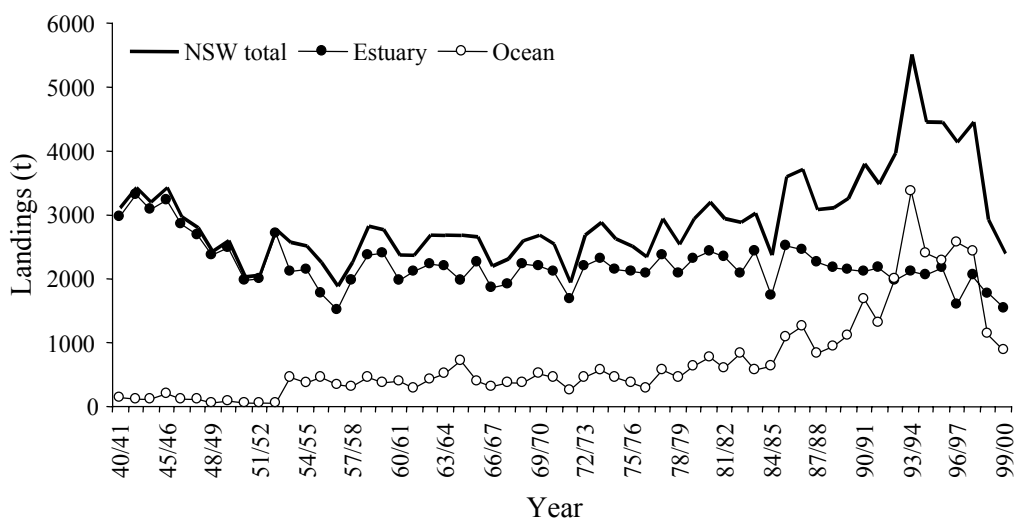


Figure 9. Annual sea mullet landings in oceanic and estuarine waters of New South Wales, 1940/41-1999/00.

Oceanic catch

Reported oceanic landings of sea mullet in NSW were stable between 1953/54 and 1979/80, averaging 431 t annually (Fig. 9). Production subsequently began to increase and reached a maximum of 3385 t in 1993/94. Oceanic landings remained above 2000 t until 1997/98, after which time a rapid decline was observed. Landings were 882 t in 1999/00 (Fig. 9).

Oceanic landings of sea mullet in NSW are highly seasonal and mainly occur from April to May (Fig. 10). This period coincides with the occurrence of pre-spawning, migratory schools in coastal waters. The ocean fishery primarily targets pre-spawning females during this 'travelling season'. Southern fish commence migration earlier than northern counterparts, and so the sea mullet ocean fishery commences, and finishes, earlier in southern NSW waters (Fig. 11). From 1994/95 to 1998/99, an average of 61% of oceanic landings occurred in April (Fig. 10). This is greater than in previous years, e.g. 40% in April from 1984/85 to 1988/89. Long-term trends in the monthly distribution of catch suggest a gradual shift towards the targeting of pre-spawning fish in April.

The summer 'hardgut' migration (December-February) has been an occasional component of annual oceanic landings (Fig. 12). Historically, this small summer fishery has been of economic significance because it occurred at a time of year when demand and prices were relatively high. However, oceanic landings between December and February have declined to almost zero in recent years.

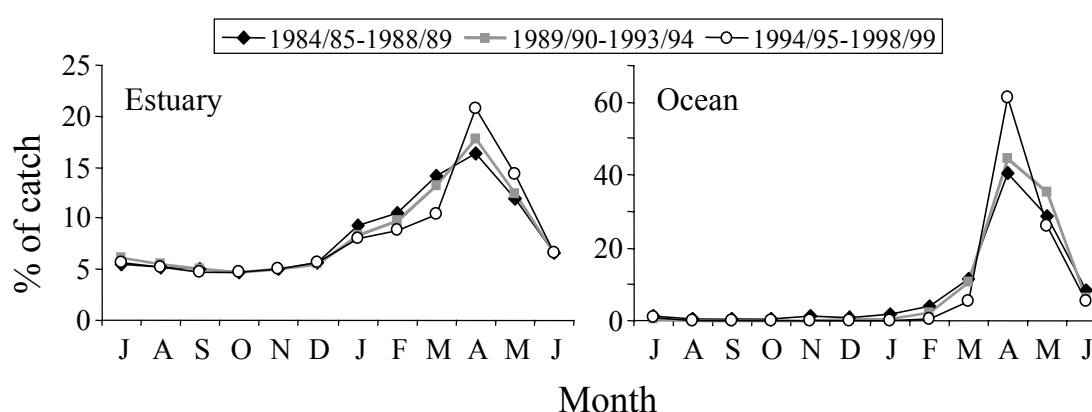


Figure 10. 5-year average distributions of sea mullet landings among months within NSW estuarine and oceanic waters.

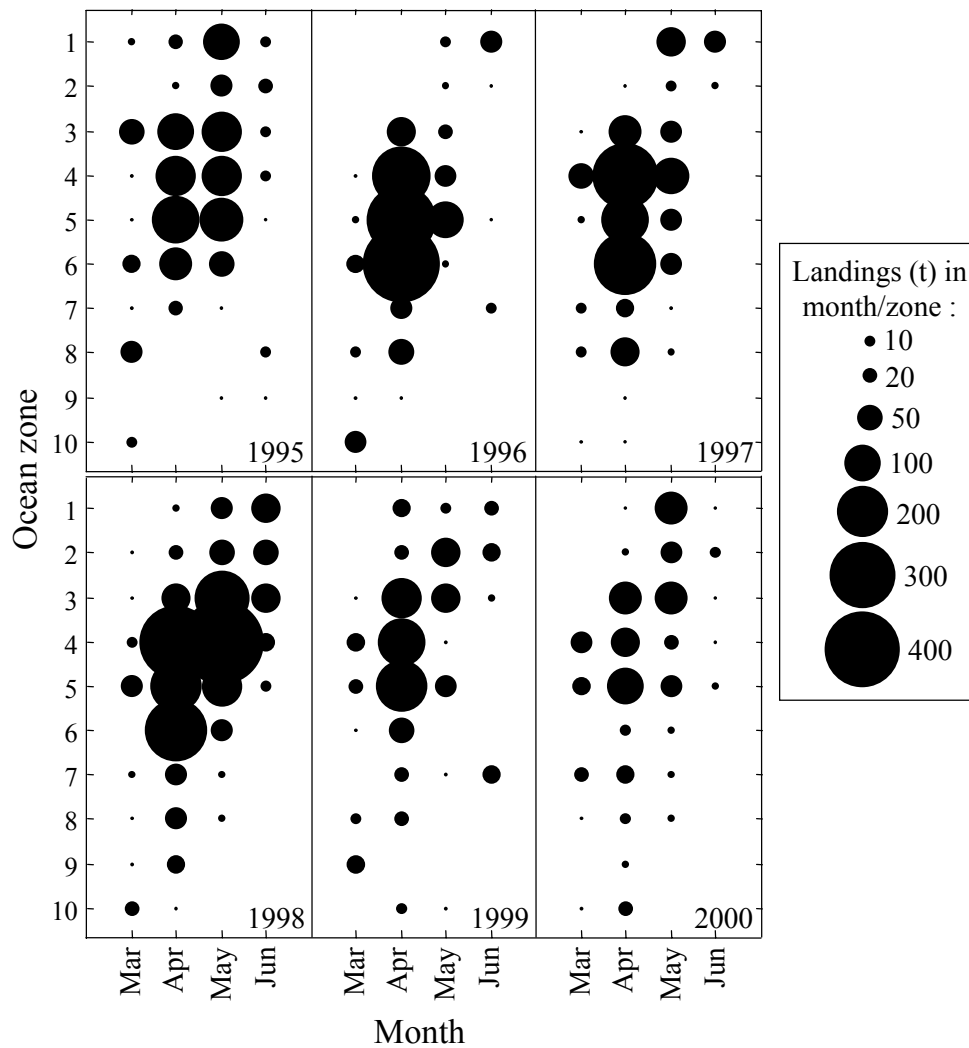


Figure 11. Distribution of oceanic landings, March to June, 1995 to 2000. Circle size reflects annual landings occurring in month/zone. (1° latitude per zone, commencing with Zone 1 in north)

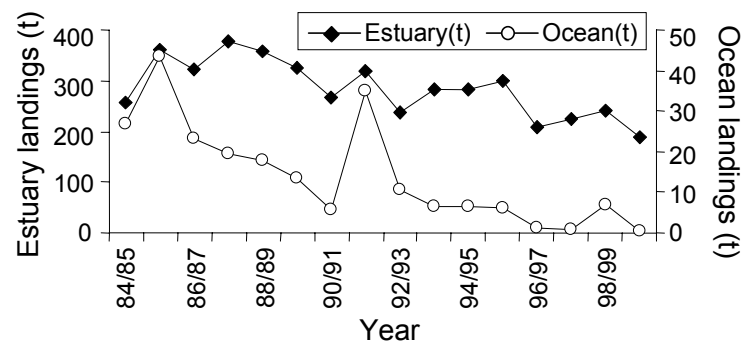


Figure 12. Total NSW oceanic and estuarine landings of sea mullet during the annual 'hardgut' season (December - January), 1984/85 to 1999/00.

There is considerable annual variability in the magnitude of landings within and among ocean zones. From 1994/95 to 1998/99, 80% of annual landings occurred within zones 3 to 6 (Fig. 13a). Zone 4 yielded the highest average annual landings, although the average number of fishers reporting sea mullet landings each year was higher in zone 5 (Fig. 13a, b). The zones south of Sydney (zones 7-10) produced the lowest annual landings, and the contained lowest number of fishers reporting landings. The average annual catch of individual fishers tended to be similar among zones, with slightly higher catch rates in zones 4 and 6 (Fig. 13c).

Catch trends in ocean zones 3-6, where landings are highest, contribute most to trends in total NSW production. The relatively high total landings in ocean waters from 1992/93 to 1997/98 was attributable to substantial increases in landings within zones 3-6 during these years (Fig. 14). Similarly, recent declines in total landings after this period also reflected catch trends in zones 3-6.

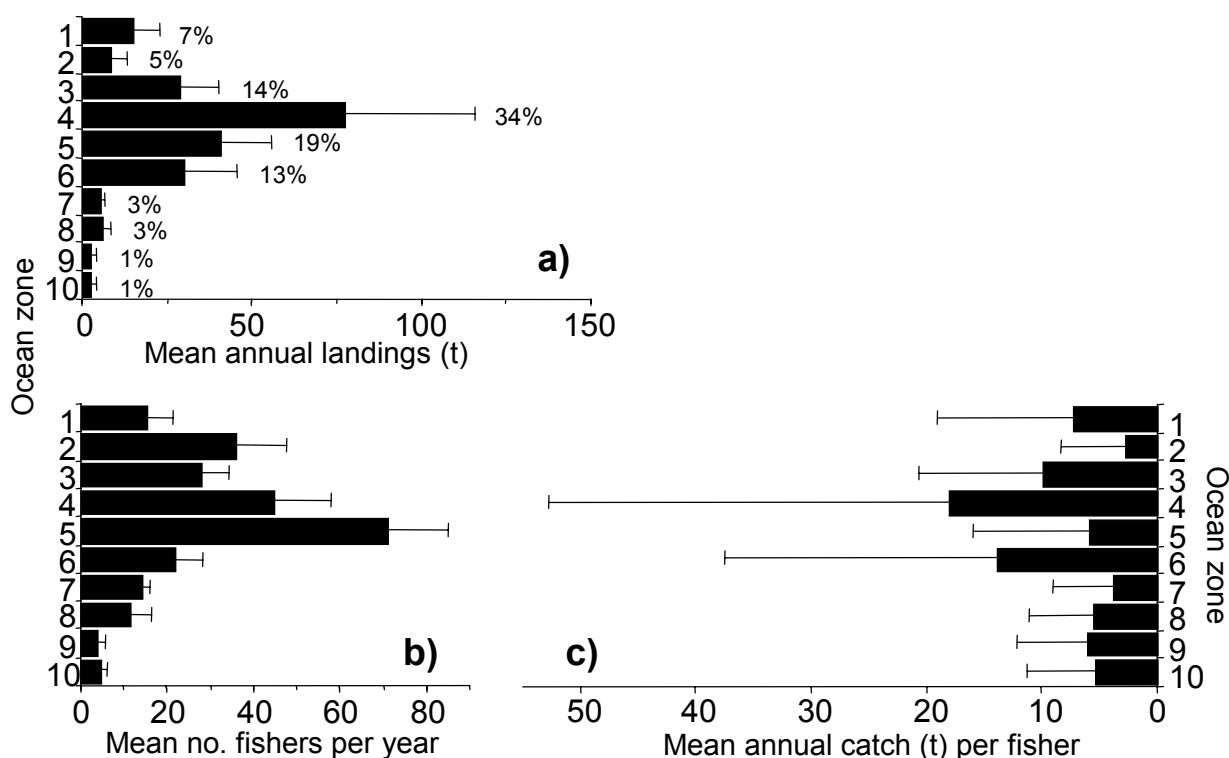


Figure 13 Mean (+s.d.) annual **a)** sea mullet landings, **b)** number of ocean haul fishers reporting sea mullet landings, and **c)** landings per fisher. 1994/95 to 1998/99, landings within New South Wales to ocean zones. (Ocean waters only; 10 latitude per zone; 'Landings per fisher' does not include zero catches)

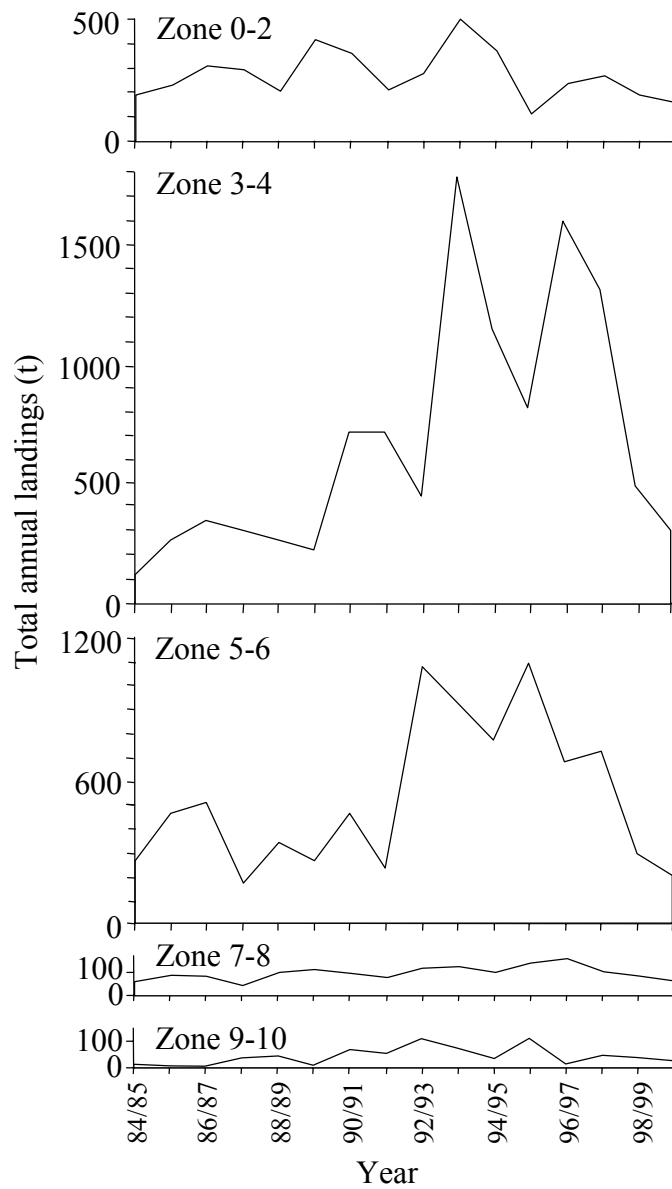


Figure 14. Annual sea mullet landings within New South Wales ocean zones, 1984/85-99/00. (Ocean waters only; 1° latitude per zone)

Estuarine catch

Reported estuarine landings of sea mullet were relatively stable between 1950/1 and 1985/6, averaging 2136 t per year (Fig. 9). After 1985/86, estuarine landings steadily declined. A minor decline in total estuarine landings coincided with increases in oceanic landings during the late 1980's and early 1990's. The rate of decline in estuarine landings increased when oceanic catch levels began to decline after 1992/93 (Fig. 9). Total estuarine landings were 1531 t in 1999/00.

Estuarine landings of sea mullet in NSW exhibit similar seasonality to those from ocean waters (Fig. 10). As in the ocean fishery, the greatest proportion of total landings occur in April (21% of total landings from 1994/95 to 1998/99). The haul net sector of the sea mullet fishery targets pre-spawning fish that aggregate within the lower reaches of estuaries prior to, or during, migration. Virtually all landings by estuary hauling nets occur in April and May (Fig. 15). Mesh nets are used to target pre-spawning fish, but also to target fish at other times of year, within upper and lower estuarine areas. Mesh net landings are slightly less seasonal than hauling net landings, although highest mesh net landings also occur in April and May (Fig. 15).

Historically and recently, sea mullet production within the Clarence River has been the highest among NSW estuaries (Fig. 16), averaging 454 t annually between 1994 and 1998. The next highest producer over the same period was Myall Lakes/Port Stephens, which averaged 241 t per year. The Clarence River and the Myall Lakes/Port Stephens region also contained the highest number of fishers reporting sea mullet landings (Fig. 17b). In general, the distribution of sea mullet fishers among estuaries is similar to the distribution of sea mullet catch among estuaries. As a result, average annual production by individual fishers tended to be similar among major estuaries (typically 2-4 t per annum, Fig. 17c).

Landings in major estuaries have either declined slightly or have been stable since 1985/86 (Fig. 16). Most recently, from 1997/98 to 1999/00, annual landings in each of the Clarence, Hunter and Hawkesbury Rivers, and in Wallis Lake and in Myall Lakes/Port Stephens declined in successive years. Lake Macquarie was the only major estuary to experience an increase in production in recent years. No major estuary has experienced a sustained increase in production since 1985/86. No other trends in annual catch were common among major estuaries, suggesting that some factors influencing catch levels differ among estuaries (Fig. 16).

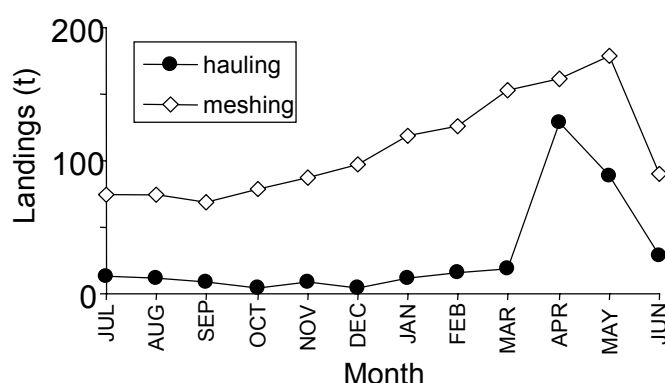


Figure 15. Total monthly landings of sea mullet by mesh and haul nets within NSW estuaries in 1998/99.

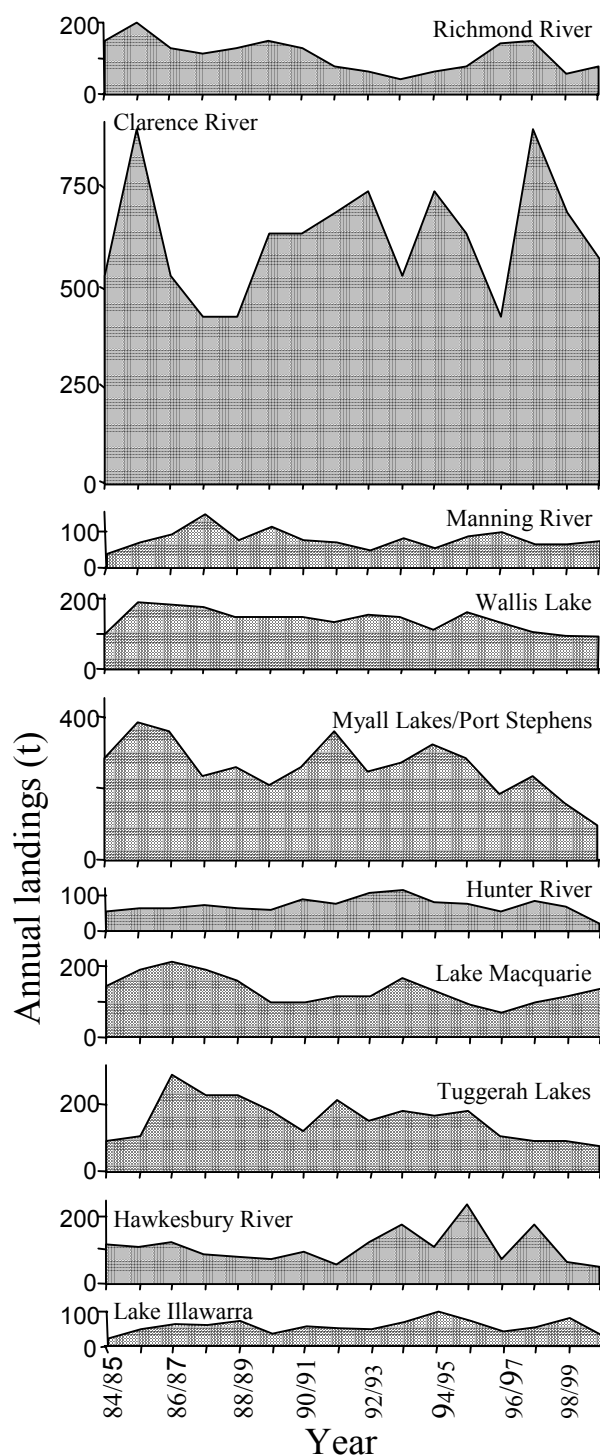


Figure 16. Annual sea mullet landings within major New South Wales estuaries, 1984/85 to 1999/00. Estuaries listed are top ten recent producers of sea mullet.

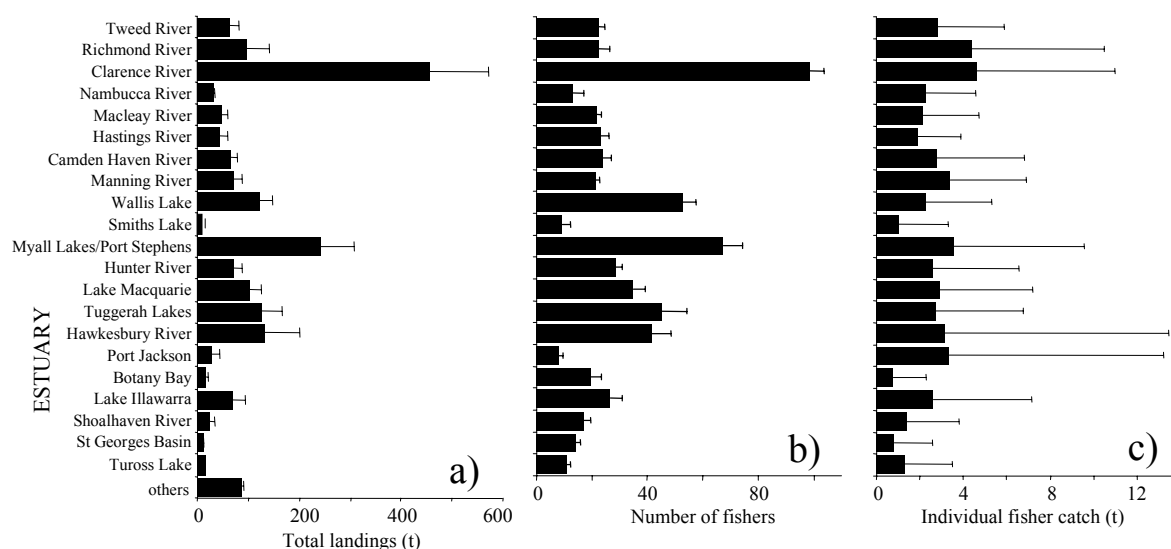


Figure 17. Mean ($\pm$ s.d.) annual **a)** sea mullet landings per estuary, **b)** number of sea mullet fishers per estuary, and **c)** landings per fisher, within major NSW estuaries, 1994/95 to 1998/99. ('other' estuaries account for 5% of landings)

Environmental influences on catch levels

Various environmental factors are believed by fishers to influence the timing and magnitude of commercial catches of sea mullet. The commencement of spawning migrations along the NSW coast usually coincides with a distinct change in weather conditions, including the onset of westerly winds and cooler temperatures. The timing of this change is variable but tends to occur in April. Prior to this seasonal change, heavy rain can result in the emigration of adults and juveniles from estuaries, associated with flood waters. Loss of fish during flooding can result in reduced annual landings within affected estuaries. Importantly, females forced to undertake such early migrations contain low quantities of roe. Hence, even if fishers are able to catch these fish, a significant loss of income is incurred (see section on Fishery Value).

Weather and ocean conditions affect the efficiency of haul net operations. Hauling is difficult in heavy swells and conditions of poor visibility will reduce the ability of fishers to locate schools.

Fish behaviour can also affect catch levels. Some schools migrate northwards in close proximity to the shore line, and are vulnerable to the beach haul fishery. However, other schools travel away from the coast after leaving the estuary and are inaccessible to fishers. It is unclear whether these fish remain in offshore waters to migrate and spawn, or return to the coast.

Various anthropogenically induced disturbances can affect sea mullet catch levels at small scales. For example, the passage of a boat through a school can disperse fish and prevent capture by fishers. Ocean plumes, such as from dredging or outfalls, can alter the direction of travel away from the coast and also prevent capture. In addition, degradation of habitat (particularly water quality) is known to result in disease and mortality of sea mullet in NSW estuaries.

Historical reporting of fishing effort

For decades, NSW commercial fishers have been required to report monthly catch of each species and some measure of their monthly effort. Due to various factors, the level of detail by which these statistics have been reported has fluctuated over the years. In particular, changes to the format of monthly returns lodged by ocean haul fishers have impacted significantly on the consistency of catch and effort statistics.

From 1977 to 1990, fishers (as individuals or as a crew) reported catch by species, and details of total effort (by any method, in days) by region. For this period, monthly catches of each species can not be confidently associated with particular locations or fishing methods. In attempting to calculate a catch rate, it is generally only possible to determine species catch by month (or year) and by class of water (i.e. ocean v. estuary) during this period.

From 1990 to 1997, fishers were required to submit an individual monthly catch return. The format of this return differed to pre-1990 returns, but the information requested was essentially similar. Unfortunately, differences in formatting or wording of returns can alter the interpretation and response of fishers to essentially the same questions. Estimates of catch rate (e.g. kg per fisher day) often show a large fluctuation, which is not reflected in total catch level, immediately after a change in format of returns. In calculating a catch rate from 1990 to 1997, it is generally possible to determine species catch by month and location. However, it is generally not possible to relate days of effort or fishing method to species catch during this period.

Since 1997, individual fishers have been required to report monthly catch of species by location and method. Days of effort spent either fishing or searching by each method/location have also been requested. However, this effort information has clearly not been reported consistently among fishers. Since 1997, it is generally possible to calculate species catch by month, location and fishing method. However, it is not possible to accurately associate catch with days of effort.

In summary, catch and effort associated with individual species have been reported at varying levels of detail throughout the history of the ocean haul fishery. Lack of information about fishing effort prevents any confident estimate of catch-per-unit-effort (CPUE). Changes in the format of fisher returns limit the usefulness of any comparisons of data over time. Fluctuations in reported catch and effort, particularly those occurring around 1990 or 1997 when the format of returns was altered, must be interpreted with caution. In order to relate pre- and post-1990 catches, only information relating to species catch by time (month, year) can confidently be used.

Catch rate as an indicator of stock status

To assess the status of a fish stock, some relative measure of abundance is usually required. Commercial catch levels can fluctuate for reasons other than changes in fish availability. In particular, the level of fishing effort (no. boats, no. fishers, no. days fished, etc) will affect catch level. Hence, it is useful to correct for the effect of fluctuating effort, and to calculate CPUE.

The most appropriate unit of effort to be reported for stock assessment purposes will vary among fishing methods and among species. Unfortunately, the most 'appropriate' unit of effort may be logistically difficult for fishers to measure, and so a less informative unit is often substituted. That effort which is considered 'appropriate' and 'feasible' to report has changed numerous times in the history of the NSW ocean haul fishery. The changes reflect changes in technology and scientific opinion.

Arguably, a useful unit of effort for ocean hauling is catch 'per crew'. Catch 'per fisher' is a less ideal index of fish abundance. Under conditions of constant fish abundance and crew catch levels, individual fisher catch levels will still fluctuate depending on the number of fishers per crew. This in turn will fluctuate according to a range of factors.

Prior to 1990, some ocean haul skippers may have reported total crew catch, rather than their individual share of this catch. Estimates of average fisher catch rate from this period may be too high for this reason. After 1990, most fishers probably reported their individual share of the crew's monthly catch. Unfortunately, in all years it is difficult to verify whether a particular monthly return lists the whole or partial catch of a crew. Conversely, it is also difficult to group separate returns of individual fishers by crew in order to calculate catch per crew, as crew memberships

were not defined in NSW Fisheries records. Therefore, catch 'per crew' cannot be calculated for any recent period in the ocean haul fishery. The less useful measure of catch 'per fisher' (in months or years) can be calculated with some confidence after 1990.

To allow some comparison of sea mullet catch and effort data among years, notwithstanding the problems outlined above, 'annual catch per fisher' has been calculated in this report. This measure of catch rate was estimated for ocean haul net fishers and estuarine mesh net fishers. Calculations for each fisher type were based on catch and effort of a select group of fishers, to reduce variability in estimates that would arise via the inclusion of fishers that did not regularly target sea mullet.

Certain factors must be considered in the interpretation of catch rate trends. Firstly, the likelihood of skippers reporting catch of the entire crew (as opposed to only their personal share of catch) has declined through time. For this reason, individual fisher catch rate in earlier years may have been over-estimated, and some declines in individual fisher catch rate through time may be an artifact of this change.

Secondly, changes in fishery management and the format of monthly fisher returns may have affected fisher behaviour and the level of reporting of catch and effort data. In particular, access to the Ocean Haul fishery was restricted after 1995, and the format of monthly fisher returns was altered in 1997/98. These changes are likely to have affected catch and effort statistics, although the nature of the effects are unclear.

Thirdly, fishers report that the average number of fishers per crew has declined in recent years. This is partly due to the restriction of the fishery, causing a decline in the number of endorsed fishers available to work. It is also partly due to declines in the price paid for sea mullet in recent years. It has become less economically viable to divide catch and profits among a large crew. Reductions in crew size may artificially elevate individual fisher catch rates, even during conditions of stable, or declining, crew catch rates.

Finally, few fishers reported landings in every year. However, annual returns with zero catch were not included in calculations because it was not possible to distinguish between years of zero effort with no catch and years of some effort with no catch. Hence the number of fishers contributing to annual averages is variable among years. Also, for this reason, averages presented here may over-estimate true catch rates.

Trends in oceanic catch rate

Catch and catch rates of ocean beach haul net fishers were analysed by grouping fishers by zone. Ocean haul fishers were selected for analysis if i) sea mullet catch history was >10 t between 1990/91 and 1999/00, and ii) landings were reported in 1997/98, 1998/99, 1999/00 and in at least 2 other years since 1989/90. These criteria were used to define a group of relatively experienced sea mullet fishers with recent catch history. Catch history in 1997/98, 1998/99, and 1999/00 was emphasised because data from these years was considered relatively reliable and provided recent fishery information. An average catch rate was also calculated for all ocean haul fishers (i.e. regardless of catch history) to allow comparison with the experienced fisher group.

Average, annual catch rate of experienced fishers in zones 1-3 fluctuated between 2.5 and 13.4 t y⁻¹ from 1990/91 to 1999/00 (Fig. 18a). Minimum and maximum catch rates occurred in 1995/96 and 1999/00, respectively. The average catch rate of experienced fishers in zones 1-3 was typically higher than the average for all fishers in these zones, but catch rate trends were very similar between the two fisher groups (Fig. 18a, c). Average, annual catch rate of all fishers in zones 1-3 fluctuated between 3.2 and 10.4 t y⁻¹ from 1990/91 to 1999/00 (Fig. 18c). Minimum and maximum catch rates occurred in 1995/96 and 1999/00, respectively. In 1999/00, 31 fishers reported total landings of 323.7 t in zones 1-3.

Average, annual catch rate of experienced fishers in zones 4-6 fluctuated between 4.1 and 16.4 t y⁻¹, from 1990/91 to 1999/00 (Fig. 18e). The average catch rate of these fishers was relatively low (6.4 t y⁻¹) in 1999/00.

The average, annual catch rate of all fishers in zones 4-6 fluctuated between 5.2 and 15.2 t y⁻¹, from 1990/91 to 1999/00 (Fig. 18g). A period of relatively high catch rate occurred between 1992/93 and 1997/98. The catch rate of all fishers was relatively low in 1998/99 (5.4 t y⁻¹) and 1999/00 (6.1 t y⁻¹). During the period of high catch rates, from 1992/93 to 1997/98, the number of fishers reporting landings of sea mullet, and their total catch was relatively high (Fig. 18h). Both reached a maximum in 1997/98, when 114 fishers reported a total catch of 1595.1 t. However, between 1997/98 and 1999/00, total number of fishers reporting landings and their total annual catch, declined sharply. In 1999/00, 52 fishers reported total landings of 316.3 t in zones 4-6. Overall, annual catch and catch rate were typically higher in zones 4-6 than in other zones.

Average catch rate of experienced fishers in zones 7-10 was relatively stable from 1990/91 to 1999/00, fluctuating between 4.4 and 10.7 t y⁻¹ (Fig. 18i). This rate was generally lower than experienced fishers in other zones over the same period.

Average catch rate by all fishers in zones 7-10 increased slightly between 1990/91 and 1999/00, and reached a maximum of 8.0 t y⁻¹ in 1999/00 (Fig. 18k). Maximum total catch by all fishers peaked at 184.4 t in 1992/93, while the number of fishers reporting catch per year peaked at 36 in 1997/98 (Fig. 18l). The total number of fishers reporting landings in zones 7-10, and their total annual catch, declined between 1997/98 and 1999/00. In 1999/00, 11 fishers reported total landings of 88.4 t in these zones.

Overall, from 1990/91 to 1999/00, the catch rates of all fishers and of experienced fishers fluctuated but exhibited few long term trends within and among ocean zones. The absence of strong trends in catch rate is not surprising. Catch rate of an aggregating species such as sea mullet will tend to remain stable, even during changes in total stock abundance. Also, the method used here to calculate catch rate (which does not consider zero returns) may tend to over-estimate real catch rate.

In all ocean zones, the total number of fishers reporting sea mullet landings and their combined annual catch, declined markedly between 1997/98 and 1999/00 (Fig. 18d, h, l). In zones 1-3 and 7-10, the number of fishers declined at a faster rate than catch level. In zones 4-6, catch level declined at a faster rate than number of fishers. Declines in the number of fishers may partly result from restriction of the fishery after 1997, which prevented access to new fishers. Declines in fisher numbers and catch level may reflect decreasing abundance of fish. Unfortunately, catch rate trends are difficult to interpret because it is not known whether fishers who reported zero catch were actually fishing or not.

However, if the zero landings reported in recent years were associated with some effort, then actual catch rates may be even lower than those represented here.

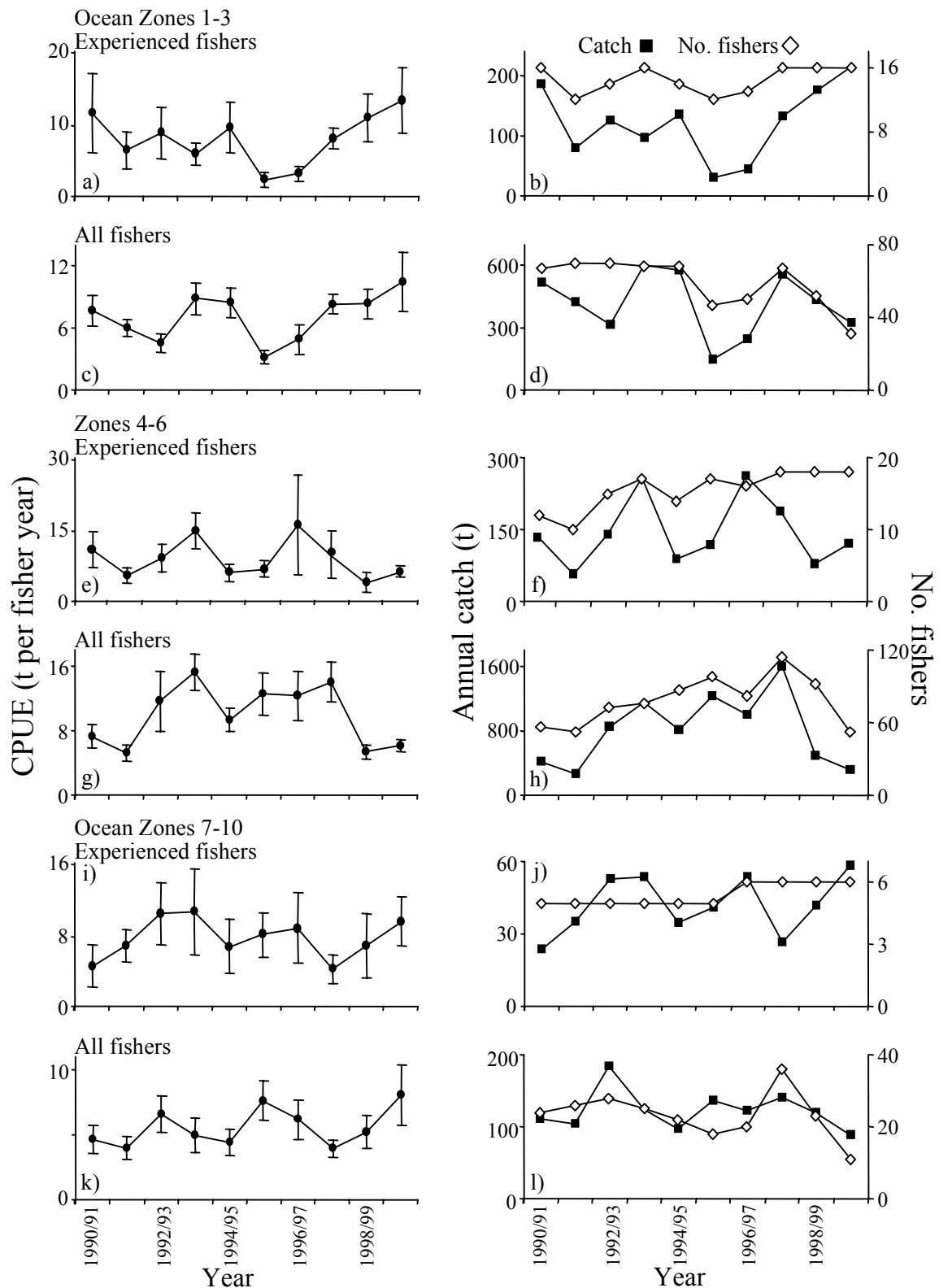


Figure 18. Mean annual catch rate (t per fisher year, $\pm$ s.d.) by haul net fishers; Total annual catch (t) of haul net fishers and number of haul net fishers and in NSW ocean zones. (see text for definition of 'experienced' fishers)

Trends in estuarine catch rate

Sea mullet within NSW estuaries are caught by haul nets and mesh nets. The proportion of landings attributable to each method is difficult to determine prior to 1997. However, estuarine hauling for sea mullet tends to be restricted to the period from March to June, and so it is reasonable to assume that most landings during other months are taken by meshing. In this report, estuarine landings from August to February are considered in calculations of estuarine catch rate. This is assumed to result in an estimate of sea mullet catch rate by mesh net fishers during the non-spawning period.

Catch and catch rates of estuary mesh net fishers were analysed by grouping fishers by estuary. The major sea mullet producing estuaries on the northern, central and southern NSW coast were considered. Estuary mesh net fishers were selected for analysis if i) total sea mullet catch history was >10 t, ii) total catch history from August to February was >499 kg, and iii) August-February landings were reported in >3 years from 1984/85 to 1999/00, or, in >1 year from 1997/98 to 1999/00. These criteria were used to define a group of relatively experienced sea mullet fishers within each major estuary.

Between 1990/91 and 1999/00, the number of experienced fishers reporting landings declined in most major estuaries (Figs. 19-21). Trends in total annual catch by experienced fishers were variable among northern and southern estuaries, but tended to decline among central estuaries. Total annual landings in southern estuaries were typically much lower than elsewhere and so trends in south coast landings had little impact on total NSW catch trends.

Overall, average catch rates of experienced fishers within most major estuaries were relatively stable (Figs. 19-21). As with oceanic landings, the lack of strong trends in estuarine catch rates was not unexpected, due to the aggregating nature of sea mullet. Between 1997/98 and 1999/00, catch rates increased markedly in some estuaries (e.g. Tweed River, Camden Haven River). However, this trend is difficult to interpret since it coincides with significant changes in fishery management in 1997/98. In general, fluctuations in catch and catch rate were not synchronous among estuaries, including those within regions, suggesting that some factors influencing catch were local to individual estuaries. In contrast, a decline in the number of experienced mesh net fishers was wide-spread, suggesting that the factors which influenced the number of fishers were common throughout the fishery.

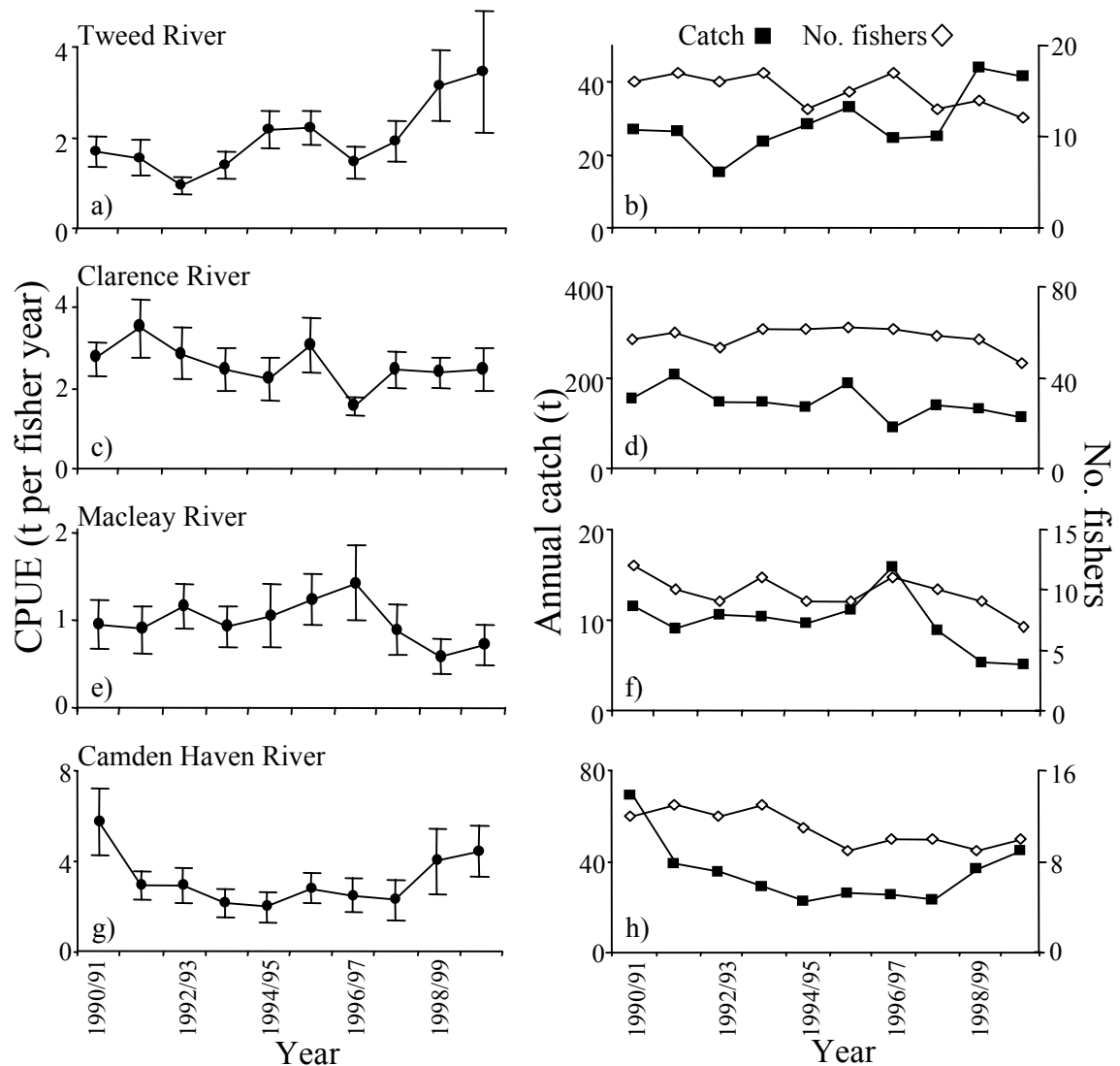


Figure 19. Catch rates, total annual catch, and number of experienced mesh net fishers in various north coast estuaries. (see text for definition of 'experienced' fishers)

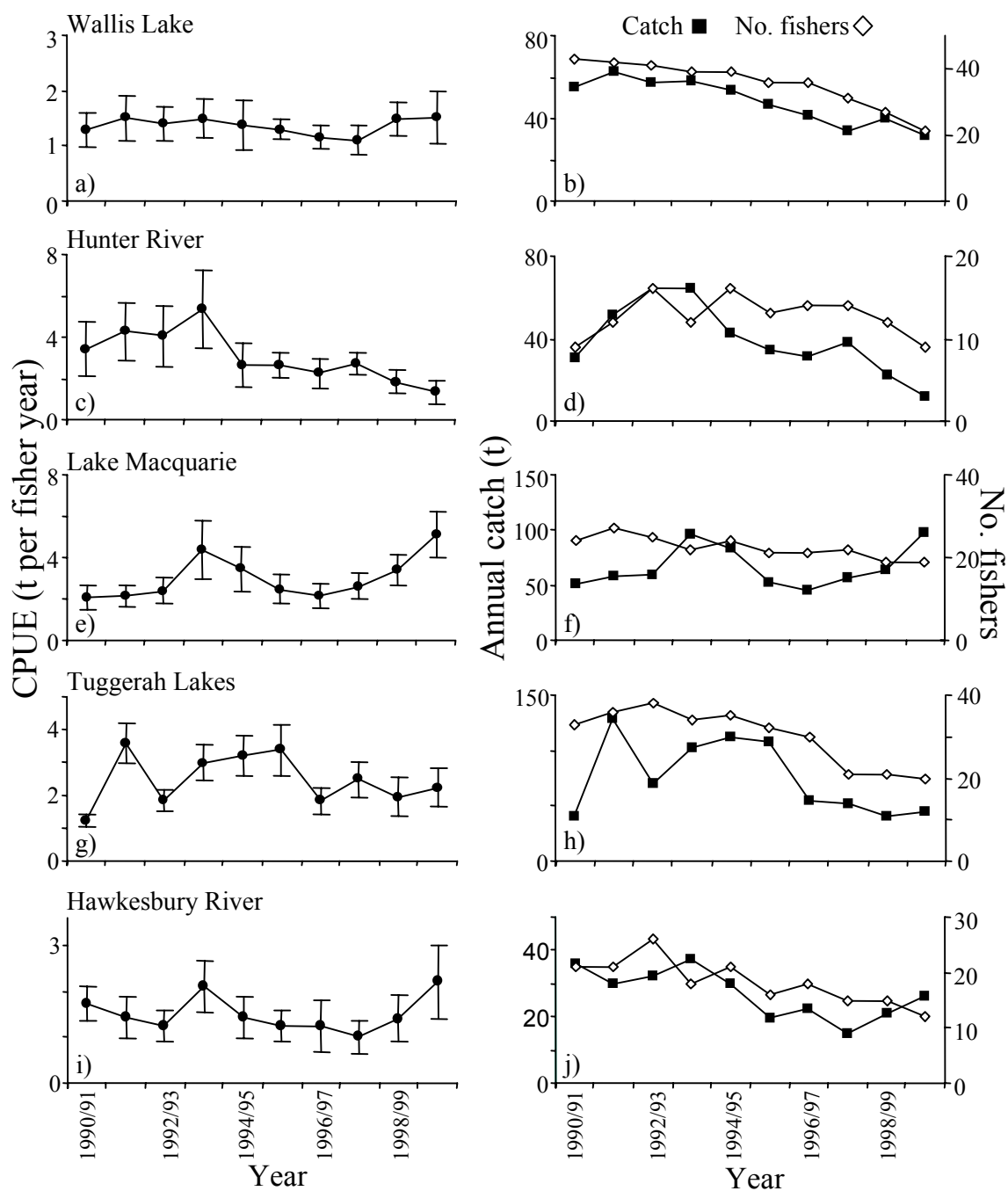


Figure 20. Catch rates, total annual catch, and number of experienced mesh net fishers in various central coast estuaries. (see text for definition of 'experienced' fishers)

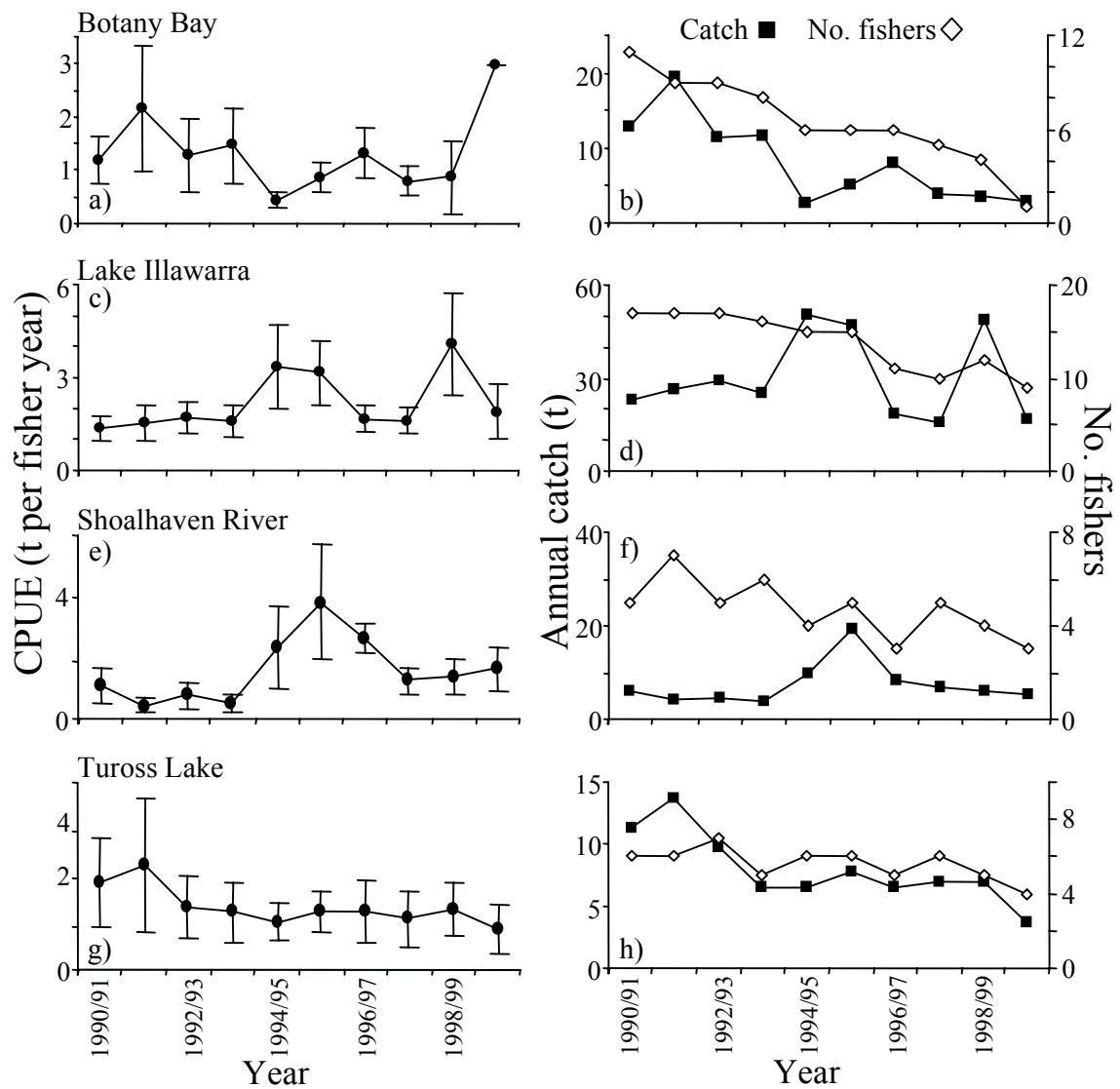


Figure 21. Catch rates, total annual catch, and number of experienced mesh net fishers in various south coast estuaries. (see text for definition of 'experienced' fishers)

NSW Fishery – Length and Age Composition

Stock size and structure are functions of recruitment, growth and mortality. The age and length composition of landings is used to infer rates of recruitment, growth and mortality. Variations in these population parameters will affect catch rate. In combination with information about stock size, these population parameters can be used to model fishery production.

Length composition of commercial landings

The lengths of sea mullet caught in NSW estuarine waters were sampled intermittently between 1939 and 1989 (Fig. 22). During this period, lengths ranged from 20 to 56 cm LCF. The modal length was relatively consistent among years, ranging between 28 and 31 cm. Only in 1977, 1978 and 1989 did the modal length exceed this range, at 35, 33, and 32 cm, respectively. Length in estuarine samples was particularly large in 1977. Reasons for this are unclear, but sample size was relatively small in 1977 compared with most other years and so may not have been representative of the fishery. In 1995, monitoring of lengths was recommenced for commercial landings in four estuaries – Clarence River, Lake Macquarie, Wallis Lake and Shoalhaven River (Virgona et al. 1998). Between 1995 and 2000, lengths of fish in estuarine samples ranged between 20 and 52 cm, with an annual mode of 31 to 33 cm LCF (Fig. 23). Overall, slight increases in modal length since 1939 are likely to reflect increases in the mesh size (and therefore selectivity) of nets used in estuaries over this period (Figs. 22, 23).

Between 1994/95 and 1999/00, limited data were available regarding length differences between female and male sea mullet in estuarine samples (Fig. 23). Generally, minimum and modal lengths were similar between sexes. This reflected a dominance of young fish in estuarine landings, and the fact that length-at-age is similar between sexes at young ages. The largest fish in samples were typically female. Within time periods, length composition of samples was variable among estuaries. Fish from the Shoalhaven River tended to be larger than fish from other estuaries. Length was also variable among time periods within some estuaries. Average length was similar among years in the Clarence River, but declined over time within Lake Macquarie and the Shoalhaven River (Fig. 23).

In 1995, monitoring of lengths of ocean-caught sea mullet was commenced. Between 1995 and 2000, ocean-caught fish were typically larger than those caught in estuaries (Fig. 24). Within this period, oceanic fish ranged from 22 to 60 cm LCF, with annual modal length ranging from 33 to 38 cm. The modal length of ocean-caught fish was smallest in 2000.

Between 1995 and 2000, females were typically larger than males in all ocean zones and years (Fig. 25). In these years, females ranged from 30 to 60 cm, whereas males ranged from 22 to 48 cm LCF. Female modal length ranged from 36 to 48 cm, while male modal length ranged from 33 to 37 cm LCF. The average length of each sex was similar among years in northern zones (zones 1-3) but more variable among years in other zones. The highest inter-annual variability in lengths was observed in females from zones 7-10. These fish also tended to be largest each year. However, limited samples were taken from these zones and so the length composition of south coast oceanic landings is difficult to assess with any confidence.

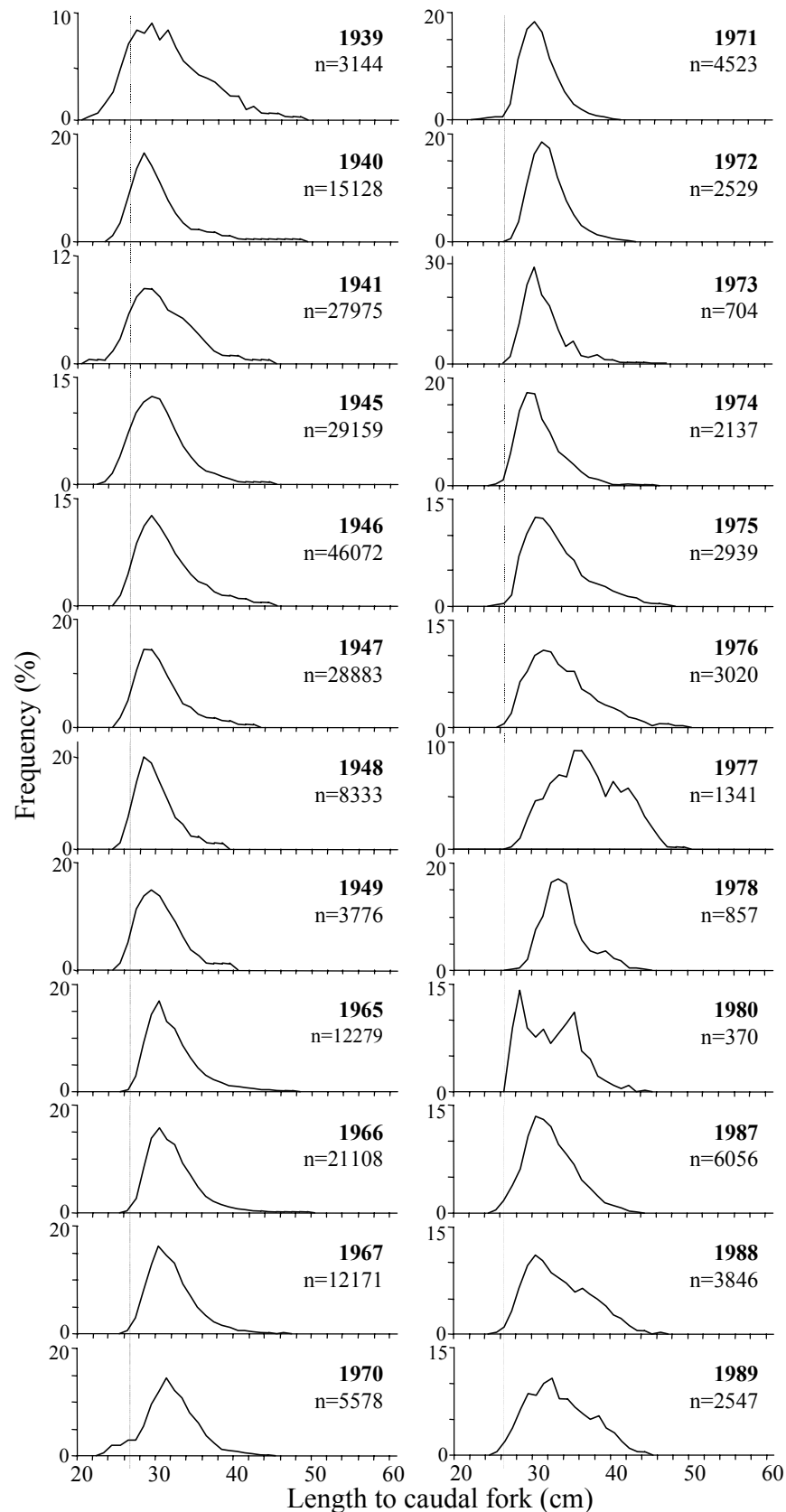


Figure 22. Length frequency distributions of sea mullet sampled intermittently from NSW commercial estuarine landings, 1939 to 1989. Note significant breaks in sampling between 1949 and 1965, and between 1980 and 1987. (Vertical lines denote minimum legal length of 266 mm)

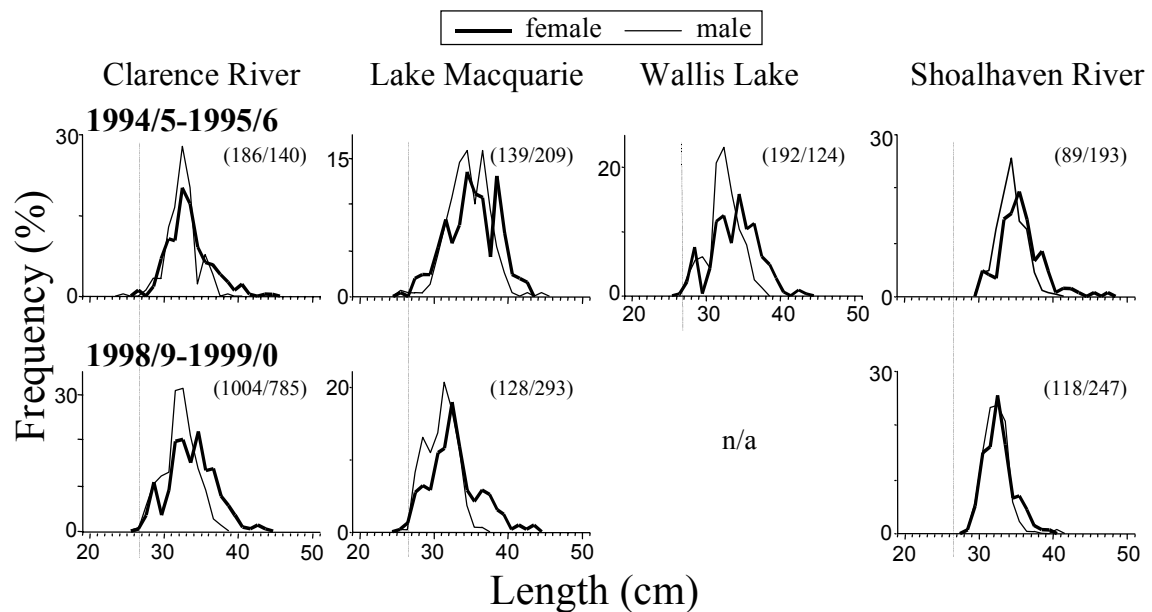


Figure 23. Length frequencies of female and male sea mullet, sampled from NSW commercial estuarine landings between August and February. Data pooled from 1994/95 and 1995/96, and from 1998/99 and 1999/00. No length data available in 1996/97 or 1997/98. (Vertical lines denote minimum legal length of 266 mm; in parentheses - number of females/males measured; n/a - no data collected)

Table 5. Percentage of male and female sea mullet below length-at-first-maturity in ocean and estuary samples, 1994/95-1999/00. (e.g. 2.5% of males caught in estuaries in 1995/96 were < 266 mm FL)

Year	males < 266mm		females < 293mm	
	Estuary	Ocean	Estuary	Ocean
1994/95	0	0	9.4	0
1995/96	2.5	0	5.7	0
1996/97	-	0.1	-	0
1997/98	-	0	-	0
1998/99	7.5	0.2	16.3	0
1999/00	0.8	0.1	2.9	0

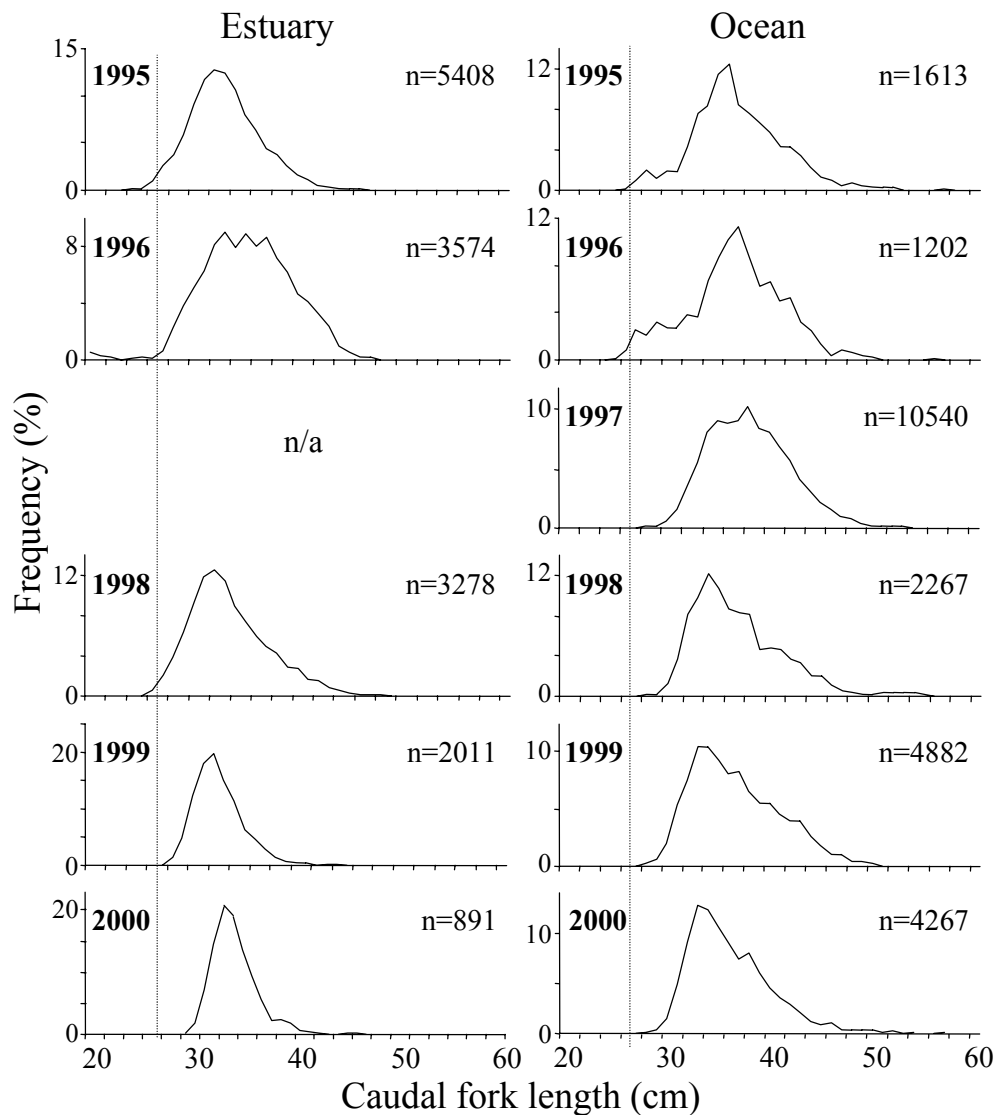


Figure 24. Length frequencies of sea mullet, sampled from NSW ocean and estuary landings, 1995 to 2000. No lengths available from estuaries in 1997. (Vertical lines denote current minimum legal length of 266 mm fork length; n – number of fish measured; n/a – no data available)

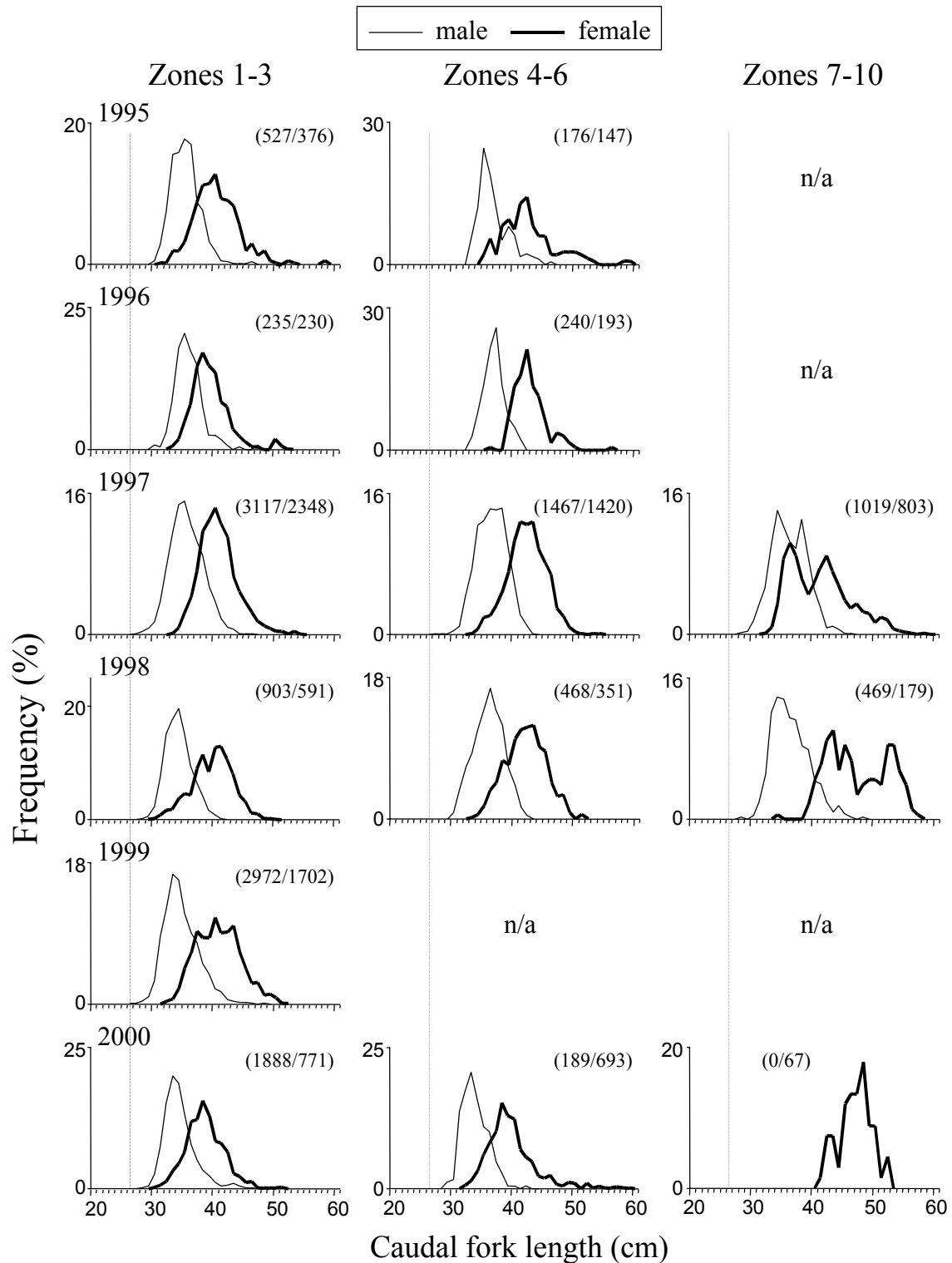


Figure 25. Length frequencies of female and male sea mullet, sampled from NSW ocean landings between March and June, 1995 to 2000. (Vertical lines denote current minimum legal length of 266 mm; in parentheses - number of females/males measured; n/a - no data collected)

Mesh sizes and minimum length

Minimum male and female lengths-at-maturity for sea mullet in NSW are 266 mm and 293 FL mm, respectively (Virgona et al. 1998). Based on these lengths, very few immature fish have been taken in oceanic landings since 1994/95 (Fig. 25, Table 5). This is not unexpected because the ocean fishery targets mature, spawning fish. However, estuarine samples have included larger proportions of potentially immature fish, particularly females (Table 5). The minimum legal length for sea mullet is 266 mm FL in NSW. This size limit may allow some male fish to spawn once before capture. However, few female fish are likely to reach maturity and spawn before becoming vulnerable to capture by commercial fishers in estuaries.

The length composition of estuarine landings varies according to seasonal changes in mesh size used by fishers. During most months, sea mullet are caught in estuaries by mesh nets with a minimum mesh size of 80 mm. However, between March and July, mesh nets with a minimum mesh size of 100 mm are used to target pre-spawning fish, particularly females. For example, in 1998, estuarine samples from 80, 83 and 100 mm mesh nets had modal lengths of 31, 34 and 38 cm, respectively (Fig. 26).

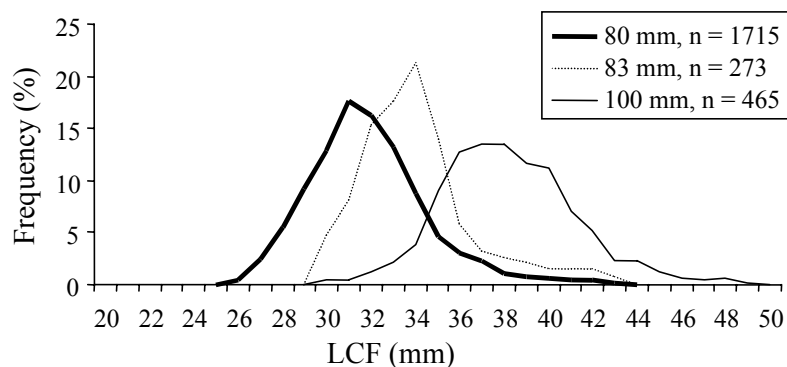


Figure 26. Length composition of commercial estuarine sea mullet landings, sampled from 80 mm, 83 mm and 100 mm mesh nets in 1998. (n - number of fish measured)

Sex ratios in commercial landings

Sex ratios in oceanic and estuarine samples was variable between 1994/95 and 1999/00 (Table 6). Males were more usually abundant, comprising 50 - 64% of individuals within samples. Limited data are available to assess the effect of mesh size on sex ratio. Nets with larger mesh sizes are designed to select large females, and limited data suggests that this does occur. In 1995, 1996 and 1998, the average proportion of females in samples from 80mm mesh net catches ranged between 50 and 59%. In the same years, the average proportion of females in samples from 100mm mesh net catches ranged between 61 and 71%. However, these values are based on very limited data and a more comprehensive study of mesh selectivity of sea mullet is required.

Table 6. Ratio (%) of male to female sea mullet sampled from NSW commercial ocean and estuary landings.

Year	Ocean		Estuary	
	male	female	male	female
1994/95	57.3	42.7	60.0	40.0
1995/96	52.9	47.1	49.3	50.7
1996/97	55.1	44.9	-	-
1997/98	62.1	37.9	-	-
1998/99	63.6	36.4	49.8	50.2
1999/00	57.6	42.4	55.6	44.4

Age composition of commercial landings

The age composition of landings provides information about stock structure and recruitment history. Monitoring of the age composition of NSW sea mullet catches commenced in 1995. Age determination is based on enumeration of opaque zones within sagittal otoliths. Formation of these zones occurs annually and is typically completed in summer (Smith and Deguara in prep.). Spawning occurs in April-May. However, a clear opaque zone is not deposited in the first summer after spawning. Hence, age of ocean-caught individuals, which were sampled in April-June, is equal to the number of clear opaque zones (N) plus 11-13 months. In this report, ages of ocean-caught individuals are therefore recorded as (N + 1) years. The age of estuary-caught individuals, sampled August to February, was assumed to equal N years plus 3-10 months. Most otoliths sampled in this period had opaque material at the margin, which was counted as 1 zone. In this report, ages of estuary-caught individuals are reported as N years. Some uncertainty is associated with ages of estuary-caught individuals. Sampling coincided with the period of opaque zone formation, and the delayed appearance of opaque material at the margins of a minority of otoliths may have resulted in the under-estimation (by 1 y) of the age of some individuals.

In ocean samples from 1994/95 to 1999/00, female ages ranged from 1 to 11 y and male ages ranged from 1 to 12 y (Fig. 28). In each year, the average age of ocean-caught females was greater than males. The dominant age class of each sex within ocean samples was 4 y, except in 1995 when the dominant age was 5 y.

In ocean samples, the average age of fish became markedly younger after 1997 (Fig. 28). This reflected the presence of a dominant age cohort (aged 5 in 1995, and therefore spawned in 1990), which declined in abundance after 1997. The more rapid decline in average age of males (compared with females) between 1996 and 1998 is explained by a higher rate of mortality acting on males in this cohort (Fig. 28). Interestingly, the majority of this cohort probably recruited to the ocean fishery in 1993-4, which corresponds to a strong peak in annual landings (Fig. 9).

Limited data suggest variable age structure among ocean zones. For example, in 1998, the age structure of females in samples from zones 1-3 was bimodal, with dominant ages of 4 and 8 y (Fig. 29). However, in the same year, the dominant female age cohort in samples from zones 7-10 was 6 y. Variation in age structure may reflect variable levels of recruitment among zones. This possibility is strengthened by the presence of localised peaks in oceanic catch levels, which coincided with years in which these locally dominant age cohorts are assumed to have recruited to the ocean fishery (assuming recruitment at age 3-4). Specifically, a northern cohort aged 8 in 1998 would have recruited in approximately 1993/94, when catch level peaked in zones 1 to 4 (Fig. 14). A southern cohort aged 6 in 1998 would have recruited in approximately 1995/96, when catch level peaked in zones 9-10. Differences in larval supply or juvenile mortality may affect recruitment to the fishery and result in contrasting population composition between northern and southern zones.

The possibility of annual recruitment variation among zones is reason for caution when using pooled age data to infer total population structure and recruitment history, and highlights the need for spatially representative age sampling. Unfortunately, interpretation of trends in age composition at the stock level is currently limited by an inadequate understanding of regional variability in age composition. More spatially representative sampling is required from future monitoring to resolve this difficulty. In particular, zones 4-6 have been previously under-represented in samples, relative to the spatial distribution of catch. Apparent trends in age structure are also made difficult to interpret because of a limited understanding of sea mullet biology and movement.

In estuarine samples from 1994/95 to 1999/00, females ranged from 0 to 9 y and males ranged from 0 to 8 y. Overall, the age composition between sexes was similar within estuarine samples and data from both sexes were pooled in Figure 30. From 1994/95 to 1999/00, the modal age of fish varied with estuary but was generally younger than in ocean samples from the same region (Fig. 29, 30). In the Clarence River and Lake Macquarie, the dominant age class was 2 y in each year (Fig. 30). In the Shoalhaven River and Wallis Lake, the dominant age class varied between 3 and 5 y. As in ocean samples (see Fig. 28), the average age of estuarine fish was younger in more recent years.

A strong presence of young fish in estuarine samples is expected. Estuaries function as sea mullet nursery habitats, and juveniles and young adults are likely to feature prominently in estuarine landings. Also the dome-shaped selectivity of mesh nets used to capture sea mullet in estuaries results in landings dominated by smaller (and therefore younger) fish than those in oceanic landings. A dominance of young fish in estuarine samples tends to obscure the age structure of the remaining older population. Hence, the age structure of estuarine samples may be a useful indicator of the magnitude of recent recruitment, but ocean samples may provide more information about earlier recruitment events.

Overall, age compositions suggest that recruitment to the ocean fishery typically occurs at 3-4 and 4 years of age for males and females, respectively. Recruitment to the estuary fishery typically occurs at 2 y for both sexes. Limited sampling of estuarine fish suggests that south coast fish may recruit 1 y later than north coast fish (Fig. 30). However, further sampling is required to assess this.

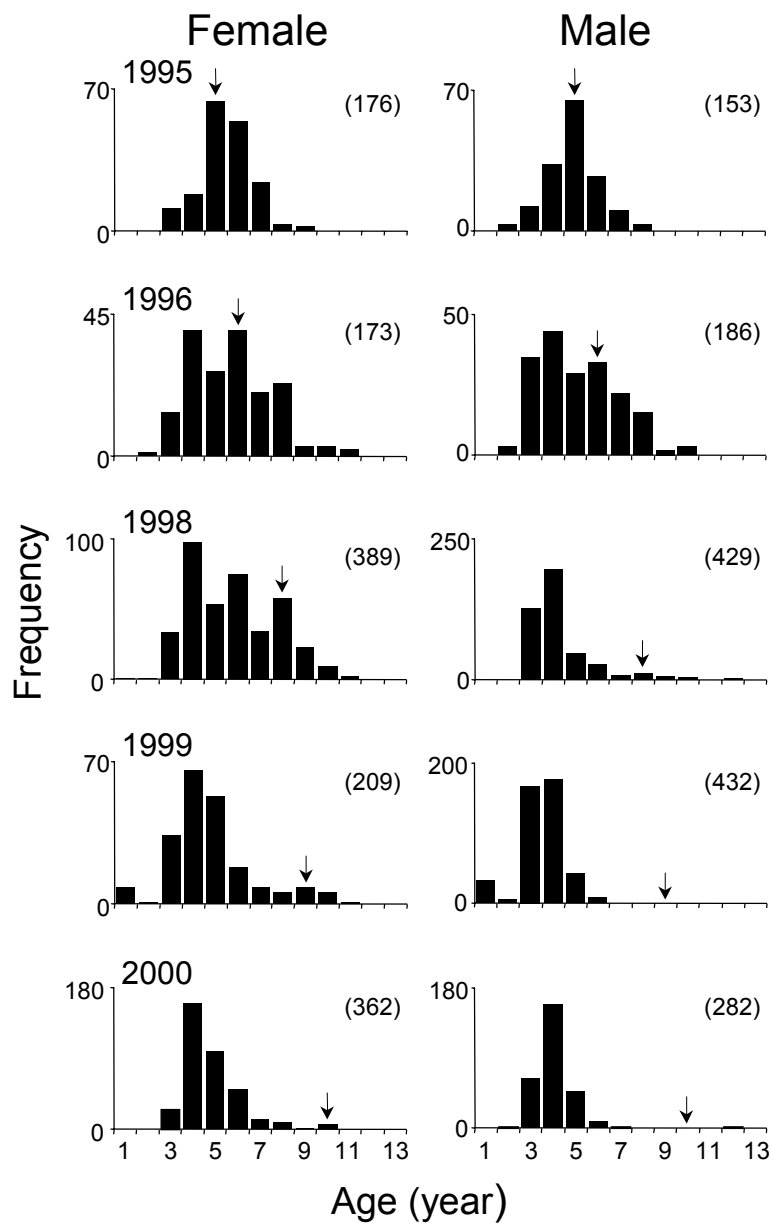


Figure 28. Age frequencies of female and male sea mullet sampled from NSW ocean landings between April and June, 1995 to 2000. (No ages available in 1997; in parentheses – number of fish aged; arrow denotes 1990 year class)

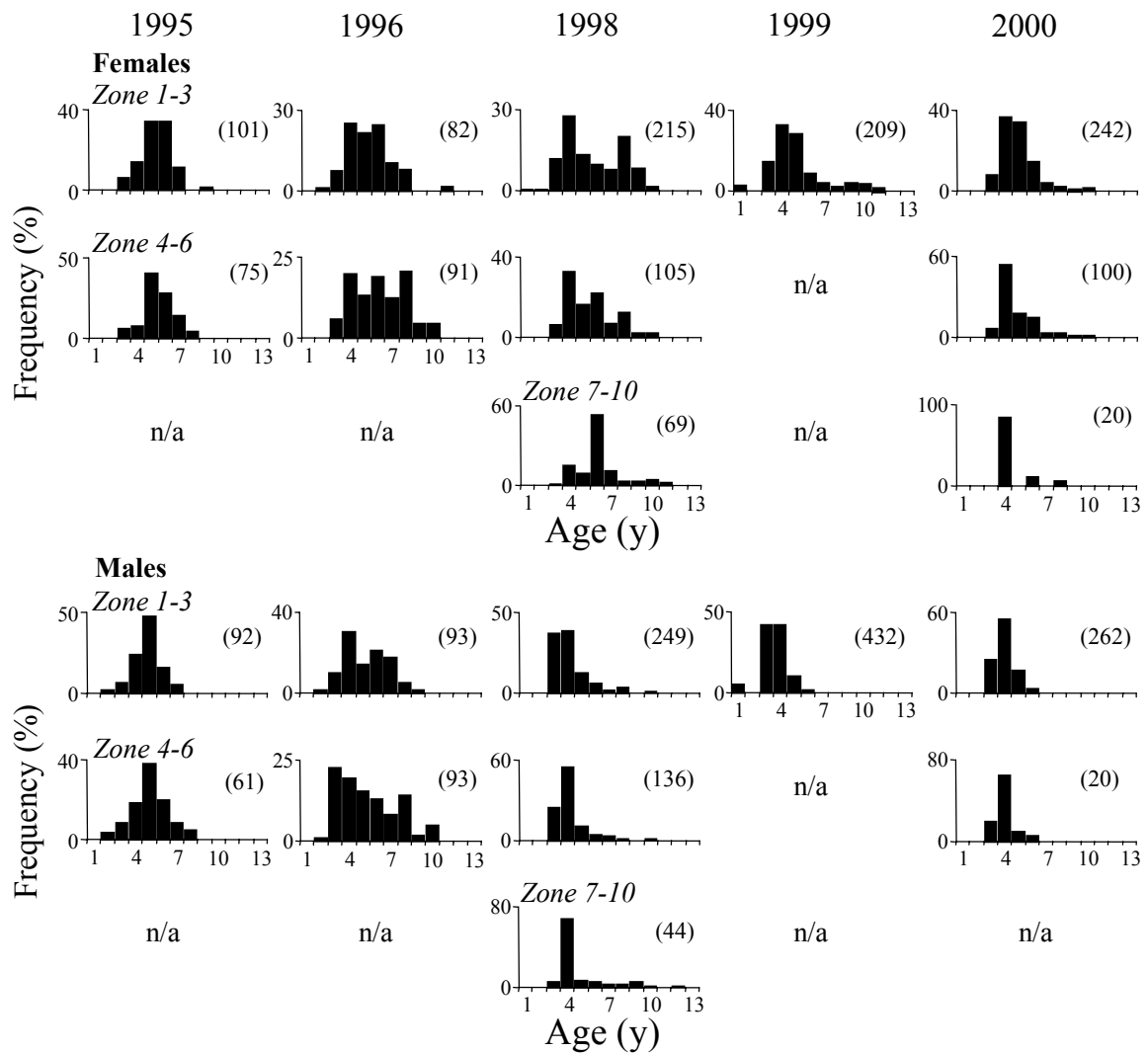


Figure 29. Age frequencies of female and male sea mullet, sampled between April and June, 1995 to 2000, pooled among NSW ocean zones. (No ages available in 1997; in parentheses - number of fish aged; n/a - no data collected; oceanic landings only; 1° latitude per zone)

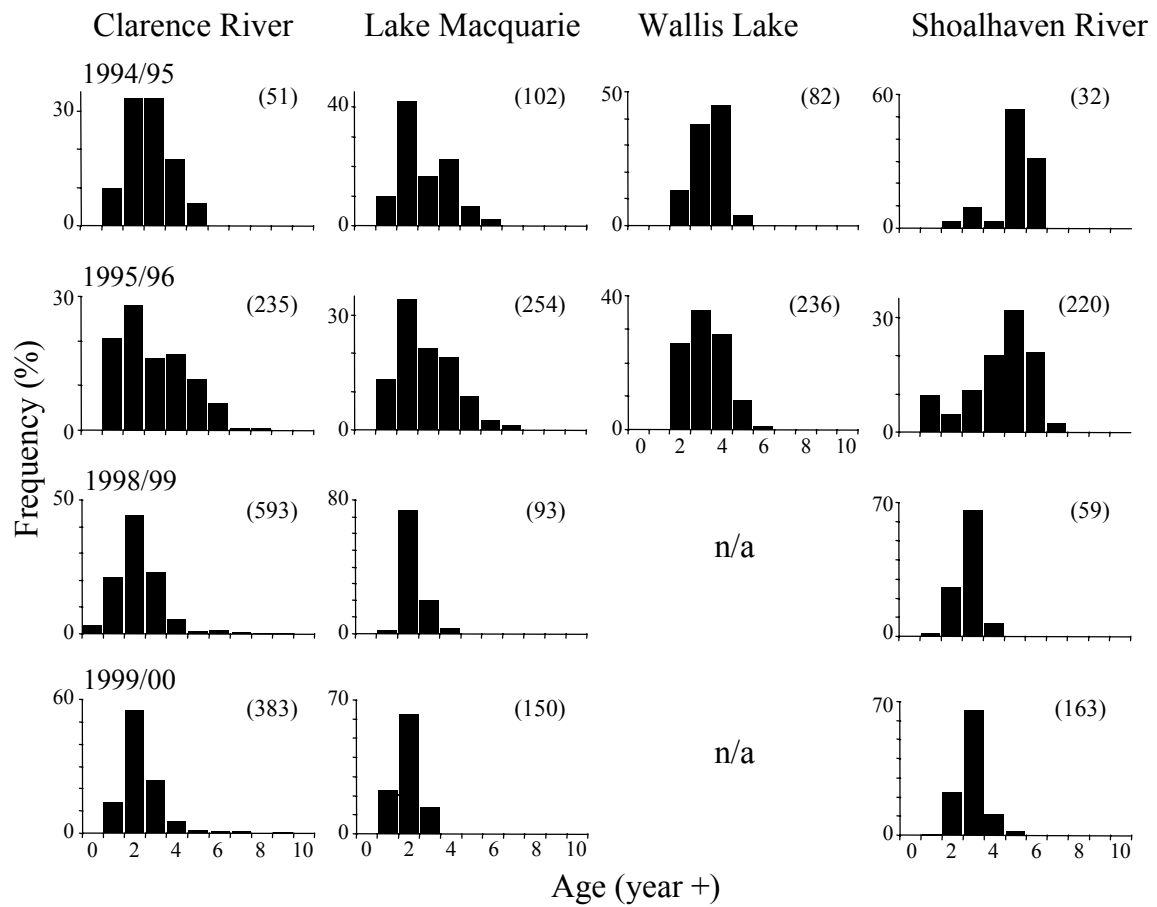


Figure 30. Age frequencies of sea mullet, sampled from NSW estuaries between August and February, 1994/95 to 1999/2000. (No ages available in 1996/97 or 1997/98; in parentheses - number of fish aged; n/a - no data collected)

Mortality

Thomson (1963) lists previous estimates of total mortality (Z) for sea mullet, ranging from 0.53 - 0.993. Within these values, natural mortality, M , was estimated to range from 0.29 to 0.58, and fishing mortality, F , from 0.2 to 0.5. Hwang et al. (1990) estimated $M = 0.33$, and $F = 0.99/1.36$ (female/male) for a Taiwanese fishery.

Total mortality (Z) was estimated from the average age structure of landings from NSW ocean zones 1-5, between 1995 to 2000 using the 'catch curve' method (Ricker 1975). Insufficient data were available from ocean zones 6-10 to allow inclusion. Data from individual years suggested total mortalities of 0.40 - 0.80 for females, and 0.46 - 1.07 for males (Table 7). Total mortalities estimated from the average age composition among years were 0.45 for females and 0.53 for males (Table 7, Fig. 31). Total mortality estimates from estuarine age compositions (not shown) were considerably higher, because of the poor representation of older fish in estuarine landings.

It is important to note that length composition, and therefore age composition, of samples is influenced by fishing gear selectivity (Fig. 26). Hence, estimates of mortality by the catch curve method will vary according to the selectivity of fishing gear used to collect samples.

It is also important to note that age composition of samples was highly variable among years, leading to variable estimates of mortality. Estimation of mortality by the catch curve method is potentially confounded by recruitment variability, which does appear to occur in the NSW fishery (as suggested by variable age composition of oceanic landings among years). There is also some uncertainty about the representativeness of available age composition data, given poor spatial sampling of landings. Other methods of estimating mortality may be more appropriate until more robust estimates of total stock age composition are available.

Using the alternative method of Hoenig (1983), where

$$\log_e(Z) = 1.44 - (0.982 * \log_e(\text{maximum age})),$$

total mortality (Z) of sea mullet was estimated to be 0.40 (female) and 0.44 (male), assuming maximum ages of 11 and 10 years, respectively.

Using the alternative method of Pauly (1979), where

$$\log M = (0.654 * \log K) - (0.28 * \log L_{inf}) + (0.463 * \log T),$$

natural mortality (M) of sea mullet was estimated to be 0.72 (female) and 0.86 (male). T (average temperature) was assumed to be 18 °C. See Table 4 for other parameter values where $t_0 = 0$. These estimates of natural mortality are relatively high, and may reflect incorrect parameter values.

Table 7. Estimates of mortality within NSW sea mullet stock from various methods. (Z – total mortality, M – natural mortality)

Year	Mortality	Female	Male	Method
1995	Z	0.80	0.94	Catch curve, annual commercial ocean landings (zones 1-5, ages >2 y only)
1996	Z	0.41	0.46	" "
1997	Z	n/a	n/a	" "
1998	Z	0.40	0.47	" "
1999	Z	0.41	0.93	" "
2000	Z	0.55	1.07	" "
1995-2000	Z	0.45	0.53	Catch curve, 5 y average of ocean landings (zones 1-5, ages >2 y only)
all	Z	0.4	0.44	Hoenig (1983)
all	M	0.72	0.86	Pauly (1979)

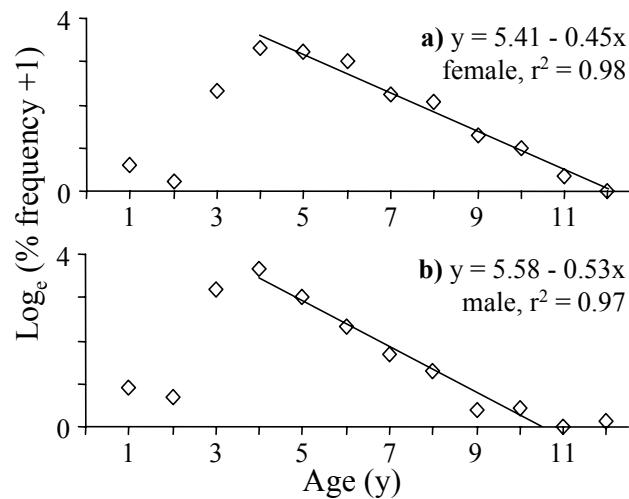


Figure 31. Age versus $\text{log}_e (\text{frequency} + 1)$ for **a)** female and **b)** male sea mullet. Data pooled from oceanic landings, zones 1-5, from 1995 to 2000. Linear regressions fitted to ages 4-12 y (females), and 4-11 y (males).

NSW Fishery - Market and Value

NSW sea mullet supply a variety of markets. Roe is extracted and exported mainly to Asia. Some whole mullet carcasses are also exported, particularly to the Middle East. Locally, whole and filleted fish are sold for human consumption, while whole fish and waste products are sold as bait.

Sydney Fish Market (SFM) prices for sea mullet have increased only slightly since 1984 (Fig. 32). There is seasonal variation in prices, with lowest SFM values obtained in autumn. Lower SFM prices at this time are a response to an oversupply of fish by the hauling sector. Despite these low prices, the most valuable component of the NSW sea mullet fishery is actually the ocean hauling sector which targets pre-spawning aggregations along ocean beaches from March to July (Fig. 33). SFM prices do not reflect the relatively high value of roed females, which are caught at this time and sold directly to processors. Female price is determined by the percentage weight of roe per catch. Hence, highest prices are generally paid in the latter part of the ocean hauling/spawning season (when ovaries are most mature). For example, in 1998/99, roe processors paid \$3-4 per kg for "high percentage" roed females. Simultaneous prices for males were approximately \$0.65 per kg (processors), or \$1.50 per kg (SFM). Some oceanic landings are sorted by fishers in order to maximise catch value – females are sent to processors, males to local markets. After roe is extracted, female carcasses are sold to local consumers for food or bait.

Estuarine hauling also targets pre-spawning aggregations during autumn. Fish targeted by this method also contribute to roe exports, and are used locally for food and bait. However, these landings are of lower total value than oceanic landings due to the lower quantities of total catch and the slightly lower roe content of females (Fig. 33). Estuarine mesh fishing produces total landings of moderate value (Fig. 33). Landings by this sector occur throughout the year and contribute to local food and bait markets.

Total value of landings within NSW waters was estimated at \$9.37 million in 1997/98 and \$4.92 million in 1998/99. The difference in value between years was largely due to the difference in quantity of total landings (Fig. 33).

In NSW, the value of mullet as a food fish is variable among regions due to several factors. Estuarine-caught sea mullet tend to have a 'muddy' flavour and are not always popular with local consumers. Ocean-caught fish tend not to have this flavour because they do not feed whilst migrating. However, whilst ocean fish are generally considered superior in taste to estuary fish, catch location is not always differentiated to the consumer. Also, in previous years handling practices have varied among fishers, leading to a product of variable quality. Although some problems (especially handling practices) have been addressed in recent years, a perception of low quality and poor taste still persists with many consumers.

Consumer education and quality assurance procedures may further improve the marketability of sea mullet as a food fish. The fact that sea mullet is already a popular product (fresh or smoked) in many regions within and outside Australia suggests that this species could gain greater acceptance in NSW markets where it is currently of relatively low value per kilogram. This was demonstrated in a recent Queensland marketing study (Kriz et al. 1993). During this study, fish were carefully handled and graded, and marketed under a brand name which consumers could then associate with a high quality product. Within one year, the brand name product attracted higher prices per kg and retail selling rates were increased, relative to the non-brand name product.

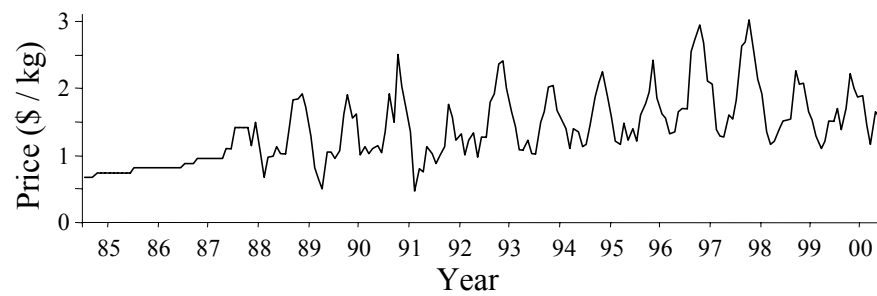


Figure 32. Average monthly price (dollars per kg) obtained for sea mullet at the Sydney Fish Market, 1985 to 2000.

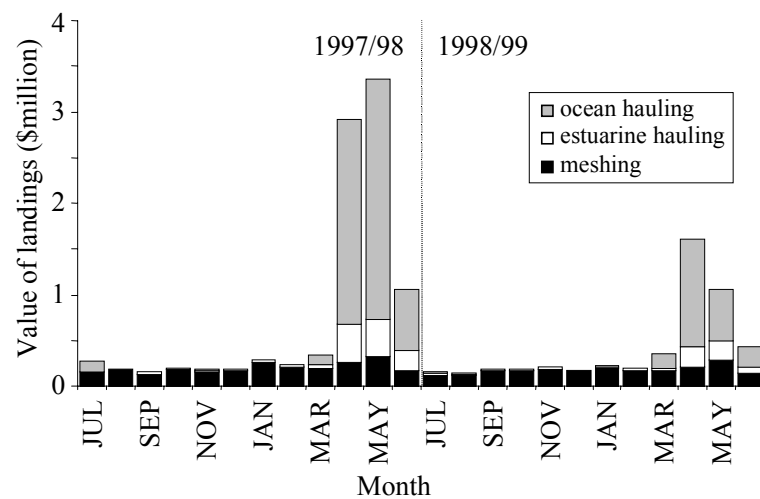


Figure 33. Monthly value of NSW sea mullet landings by method, 1997/98 and 1998/99. Total value of landings in 1997/98 = \$9.37 million, in 1998/99 = \$4.92 million.

BYCATCH AND FISHERY-HABITAT INTERACTIONS

Sea mullet form dense aggregations when travelling in ocean waters. These schools of mature, pre-spawning fish are easily identified by ocean beach fishers. Schools are not usually mixed with other species of fish, although fishers report that predatory species such as Australian salmon and tailor are occasionally caught when targeting sea mullet. For these reasons, there is likely to be limited bycatch of immature fish or non-target species associated with sea mullet catches in ocean waters. Sea mullet are caught by hauling nets in the ocean fishery. These nets are typically used over sandy habitats, where little interaction between gear and habitat is likely. However, all information about bycatch and habitat interactions in the ocean haul fishery is anecdotal and requires verification by an independent scientific observer program.

In NSW estuaries, sea mullet are caught by hauling nets and mesh nets. Bycatch and discard of non-target species and juveniles of target species by these methods in estuaries can be substantial (Gray *et al.* 2001). However, bycatch and discard of juvenile sea mullet is limited. Historically, hauling nets have been deployed over seagrass beds, as well as other habitats, in estuaries. The effects of hauling on seagrass habitats are not well documented, but may include damage/removal of seagrass leaves, epifauna and epiphytes, and disturbance of sediments. The practise of hauling over seagrass (especially *Posidonia*) will be restricted after implementation of the Estuary General and Ocean Hauling Fishery Management Strategies. Mesh nets are set in the water column and have minimal interactions with estuarine habitats.

PRODUCTION MODELLING

No biomass estimate is available for sea mullet in NSW. An age-structured population model is being developed. However, the usefulness of the model is currently limited by the quality of available data, and particularly by the absence of a reliable index of stock abundance. In the future, improvements to fisher catch returns may improve the reliability of fishery dependent data. Alternatively, fishery-independent estimates of biomass, such as from aerial surveys, may be appropriate.

STOCK STATUS

Monitoring between 1995 and 2000 has revealed declines in catch and in average age/length of NSW sea mullet landings. Such declines in fish populations can be symptoms of overfishing or reflect recruitment variability. Certainly, evidence from other populations of sea mullet suggests that commercial exploitation of this species can result in declines in stock size, recruitment, age of catch, and catch (Hwang *et al.* 1990). On the other hand, 'natural' recruitment variability is also known to be a feature of sea mullet populations (Thompson *et al.* 1989) and limited evidence from age compositions suggests this does occur within the NSW fishery. Unfortunately, in the absence of a reliable index of stock abundance, it is currently not possible to ascertain the causes of recent fluctuations in age structure and catch level. However, the recent significant decline in oceanic landings suggests reduced availability of mature fish.

Prior to 1985, the NSW sea mullet fishery experienced a long period (30 years) of relatively stable catch levels. Over this period, annual landings consisted of approximately 2000 t from estuaries and approximately 500 t from ocean waters. Such stability suggests that these 'historical' catch levels were sustainable. After 1985, quantities of oceanic landings increased very significantly and exceeded estuarine landings for a six year period during the mid-1990's. Unprecedented quantities of spawning fish were removed from the stock by the ocean fishery during this period and it is possible that the spawning component of this stock was depleted. In 1999/00, oceanic catch levels were approaching (but still above) historical levels. Importantly, historically stable catch levels may still not be sustainable with the current population structure (ie. depleted spawning biomass).

Under current market conditions, ocean-caught fish are more highly valued than estuary-caught fish. Therefore, it is likely that ocean fish will continue to be highly targeted. The impact of this harvest strategy on the sea mullet stock is uncertain, given available data.

FUTURE MONITORING AND ASSESSMENT

Sea mullet stock assessment will require spatially representative monitoring of the length and age composition of commercial landings. Although lengths are significantly easier to obtain than ages, length composition is not a particularly sensitive indicator of changes in stock structure in sea mullet due to the variation in length-at-age of adult fish. The slight decline in average length of landings that accompanied a very significant decline in average age of landings over recent years illustrates this point.

A confounding aspect of past monitoring has been minor changes in methodology among years, including changes in sampling locations. This may significantly impact on estimates of stock structure where regional differences in age/length composition of catches occur, e.g. older fish tending to occur at higher latitudes. It is possible that previously observed trends in age/length of catches may partially reflect choice of sampling locations. Clearly, consistency of sampling methodology among years is essential to allow detection of trends in commercial catch distribution and composition.

Also, future sampling times and locations must be chosen to be representative of the full distribution of commercial landings. In particular, monitoring of landings from southern locations should be continued, despite relatively low catches at these locations in some years. Data from these locations will provide information about variability in growth rates and recruitment rates. Understanding the extent of regional differences in age/length composition of catches will be useful in the planning of future sampling and in the development of appropriate harvest strategies.

Annual age monitoring will assist in interpreting recent trends in catch level and catch composition, particularly in understanding the extent of recruitment variability with the stock. However, development of a recruitment index and/or abundance index is required to address this issue fully. Age structure and catch rate within estuaries may be a useful indicator of the magnitude of recent recruitment, due to the dominance of young fish in estuaries. In contrast, such information from the ocean fishery may provide more information about earlier recruitment events, due to higher proportions of older fish.

Catch and effort data (as reported by fishers) is currently of limited use in stock assessment because of the considerable uncertainty about this information, especially effort. Abundance information reported by ocean fishers has the potential to provide an index of spawning stock size. Future reporting should incorporate daily catch and effort data at a crew level, and record all fish observed (i.e. a 'spotting diary').

Finally, future monitoring should also include the collection of reproductive data. There is currently a dearth of local reproductive information, despite the fact that the ocean fishery targets pre-spawning fish and the roe constitutes a valuable export product. Information, such as gonad weight and fecundity, would allow spatial differences in reproduction within the NSW sea mullet population to be assessed. For example, gonad maturation may commence earlier at higher latitudes. Also, relationships between egg production (fecundity, egg size) and body size are yet to be documented, and the effect of environmental influences on egg production are unknown. Such factors could influence the quality and quantity of roe production within the NSW sea mullet fishery on a regional or annual basis.

If the above information is collected in sufficient detail, future assessments of NSW sea mullet could be based on an age-structured model. Development of such a model should be a high priority for the fishery.

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