CSIRO FISHERIES AND OCEANOGRAPHY
Fisheries Synopsis No. 1

DFO/S1
SAST - 1,65 (1)

SYNOPSIS OF BIOLOGICAL DATA ON THE GREY MULLET

Mugil cephalus Linnaeus 1758

Prepared by
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COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
Cronulla, Sydney, Australia, June 1963

SYNOPSES OF FISHERIES BIOLOGICAL DATA

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The relevant series of documents are:—

FAO	**Fisheries Synopsis No.** (replacing, as from 1.1.63	FIb/S
FAO	Fisheries Biology Synopsis No.	FB/S)
	and	
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Synopses in these series present data compiled according to a standard outline described in FB/S1, (1962). Steps are being taken to form an advisory Association comprising representatives of the participating organizations, authors of synopses and other collaborators.

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CSIRO Fisheries and Oceanography
Fisheries Synopsis No.1

DFO/S1
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ERRATA

P1:5 - Line 1 should read:
"9. Lateral scales 35-36, depth 3.9-4.7 in T.L.....gairmardianus Desmaret"

fig 3 - (after Sanzo 1936) should be added to legend

p8:3 - Line 4 - "trematodes" should replace "termatodes"

SYNOPSIS OF BIOLOGICAL DATA

ON THE GREY MULLET

Mugil cephalus Linnaeus 1758

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COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
Melbourne, Australia, 1963

PREPARATION OF THIS SYNOPSIS

This synopsis was prepared originally for use in the assessment of the status of the Australian stocks. A first draft was issued in mimeograph form in August 1962.

The information contained in this synopsis is almost all derived from the literature listed in Section 8. Data have been extracted from the literature received by the library of the C.S.I.R.O. Division of Fisheries and Oceanography up to November 1962. Only references with specific identification of *M.cephalus* have been considered. Data from papers referring generally to "mullet" of unidentified species have not been included.

CONTENTS

* No information available to the author

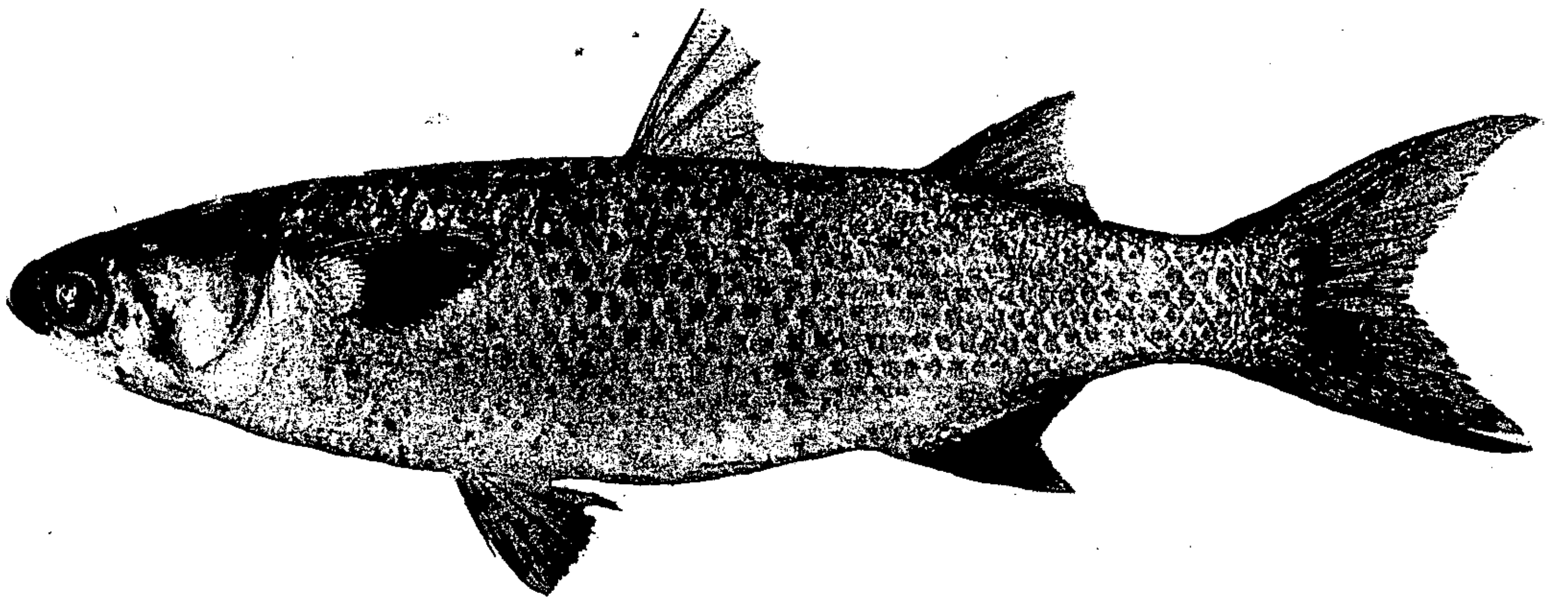

Fig. 1. The grey mullet, Mugil cephalus Linnaeus

1. IDENTITY

1.1 Nomenclature

1.1.1 Valid name

Mugil cephalus Linnaeus 1758 Systema Naturae 10th Ed.

1.1.2 Objective synonymy

None

1.2 Taxonomy

1.2.1 Affinities

1.2.1.1 Suprageneric

Phylum Vertebrata
Series Pisces
Class Teleostomi
Subclass Actinopterygii
Order Mugiliformes
Family *Mugilidae*

1.2.1.2 Generic

- *Mugil* Linnaeus 1758 Systema Naturae 10th Ed. p.316
  Genotype: *Mugil cephalus*

The generic concept adopted here is that of Thomson 1954a. "Mouth terminal; lips thin, the lower projecting horizontally, but not folded downwards; the teeth ciliform or setiform in one or more rows, tending to be lost or embedded in the lips in older fish; the outermost row are simple-tipped, the inner bifid or trifid; no papillae, lamellae or posterior folds in the lips. A symphysial knob at the tip of the lower jaw. The preorbital is moderately narrow, denticulate, and may be notched or straight along the exterior edge; maxillary not fixed anteriorly; maxilla and premaxilla not hooked downwards posteriorly; maxillary hidden when the mouth is closed. The nostrils are wide apart, the anterior nearer to the upper lip than to the posterior nostril; the posterior nearer to the eye than to the anterior; the anterior nostril is always below the level of the edge of the orbit, the posterior usually so but sometimes above orbit level. Teeth absent from vomers, palatines, pterygoids and tongue. Scales cycloid or, more usually, feebly ctenoid, frequently with a secondary cycloid squamation. Anal fin origin in advance of the 2nd dorsal origin. Adipose eyelid prominent. Gill membranes extending far forward, not broadly connected across the isthmus. Gut includes a gizzard. Basisphenoid basioccipital process, and 2nd vertebral process absent; posterior opening of the myodome narrow."

1.2.1.3 Specific

- Mugil cephalus Linnaeus 1758
(Fig. 1)

No type specimen

Type locality: European seas

Diagnosis: Fin formula: D IV, I 8; AIII, 8; P.16-17; C 18-20.)uerimana (post-larval) stage has A II, 9. Scalation : L.l. 38+42 3+5 on caudal)ase; tr. 14-15; predorsal 24-26; cheek-scales 3-4 rows. Scales cycloid in oung, feebly ctenoid in older fish. A prominent adipose eyelid almost obscures .he eye, leaving only a narrow slit over the pupil, and covering the preorbital nteriorly and running twice as far behind the eye as in front. Interorbital 'ery broad. Preorbital not notched, with only a moderate posterior border bearng 6 denticulations, the anterior with about 14.

Pectoral fin reaches 10th postopercular scale, but not to 1st dorsal origin, urned forward reaches eye but not to pupil; it has a distinct axillary scale. irst dorsal origin at 12th and second dorsal at 24th scale. Anal fin origin .arkedly in front of second dorsal origin. Gill rakers 24-36/50-76, the number ncreasing with size; pyloric caecae 2 (after Thomson 1954a).

Subjective Synonymy

Mugil albula Linnaeus 1766 placed in synonymy by Jordan and Swain (1885) whose colleagues Goode and Bean viewed type specimen

Mugil oür Forskål 1775 placed in synonymy by Cuvier (1829) with reasons

Mugil curtus Yarrell 1836 identical description

Mugil plumieri Valenciennes 1836 (non Bloch 1788) placed in synonymy by Jordan and Swain (1885)

Mugil cephalotus Valenciennes 1836 placed in synonymy by Jordan and Swain (1885) with reasons

Mugil constantiae Valenciennes 1836 placed in synonymy by Smith (1935) with reasons

Mugil lineatus Valenciennes 1836 placed in synonymy by Jordan and Swain (1885) with reasons

Mugil perusii Valenciennes 1836 placed in synonymy by Thomson (1954a) with reasons

Mugil rammelsbergii Tschudi 1845 placed in synonymy by Jordan and Swain (1885) with reasons

Mugil japonicus Schlegel 1845 placed in synonymy by Boeseman (1947) with reasons

Mugil liza Gay 1847 placed in synonymy by Jordan and Swain (1885) with reasons

Mugil berlandieri Girard 1859 placed in synonymy by Jordan and Swain (1885) with reasons

Mugil dobula Gunther 1861 placed in synonymy by McCulloch (1921) no reasons

?Mugil camptosiensis Castelnau 1861 placed in synonymy by Boulenger (1916) no reasons

Mugil ashanteensis Bleeker 1863 placed in synonymy by Boulenger (1916) no reasons

Myxus superficialis Klunzinger 1870. Day (1889) placed this in synonymy of our (=cephalus), with reasons

Mugil gelatinosus Klunzinger 1872 placed in synonymy by Thomson (1954a) on identity of description

Mugil occidentalis Castelnau 1873 placed in synonymy by Whitley (1948) no reasons

Mugil grandis Castelnau 1875 placed in synonymy by McCulloch (1929) no reasons

Myxus caecutiens Gunther 1876 identical description

Mugil mexicanus Steindachner 1876 placed in synonymy by Jordan and Swain (1885) with reasons

Mugil mulleri Klunzinger 1880 placed in synonymy by Thomson (1954a) on identity of description

Mugil platanus Gunther 1880a identical description

Mugil tongae Gunther 1880b identical description

Mugil marginalis De Vis 1884 placed in synonymy by Thomson (1954a) no reasons

Mugil hypselosoma Ogilby 1897 placed in synonymy by McCulloch (1929) no reasons

Myxus barnardi Gilchrist and Thompson 1914 placed in synonymy by Smith (1935) with reasons

Mugil monodi Chabanaud 1926 placed in synonymy by Fowler (1936) with reasons

?Myxus lepidopterus Mohr 1927 identity of description

?Myxus tincoides Mohr 1927 identity of description

?Myxus niger Mohr 1927 identity of description

Mugil peruanus Hildebrand 1946 identity of description

Mugil galapagensis Ebeling 1961 identity of description

Key to the species of Mugil

1. Anal fin soft rays 8 ....(2)
   Anal fin soft rays 9 ....(5)

2. First dorsal soft rays 9, scales cycloid......... catalarum Whitley
   First dorsal soft rays 8, scales ctenoid.......................(3)

3. More than 37 lateral scales.......................cephalus Linnaeus
   Fewer than 37 lateral scales...................................(4)

4. Lateral scales 31-34, depth 4.2-5.0, head 3.7-4.0 in S.L.......liza Valenciennes
   Lateral scales 29-32, depth 3.3-3.4, head 3.3-3.6 in S.L........... trichodon Poey

5. Lateral scales 31-32...............................georgii Ogilby
   Lateral scales more than 32....................................(6)

6. Lateral scales 42-46, transverse scales 15..........incilis Hancock
   Lateral scales fewer than 43, transverse fewer than 14..........(7)

7. Lateral scales 37-42...(8)
   Lateral scales 36 or fewer.....................................(9)

8. Lateral scales 33-42, teeth fine but visible without lens.......... curema Valenciennes
   Lateral scales 37-39, no teeth....................robustus Gunther

9. Lateral scales 35-36, depth 3.9-4.7 in T.L............gairmardianus Desm
Lateral scales 32-35, depth 4.8-5.6 in T.L.....................(10)

10. Preorbital emarginate and denticulate................engeli Bleeker
Preorbital straight-edged, not denticulate...cunnesius Valenciennes

1.2.2 Taxonomic status

This is a morpho-species. Linnaeus' description could not apply to any Mugilid; e.g. DI with 5 spines, anal variously given as 3/12, 3/13 and 10. However, Linnaeus' references imply that he meant the fish known to the Romans as cefalus and to modern Italians as cefalo. At times other species notably Liza aurata have been confused under name cefalo, but are usually distinguished as cefalo morbido. Cuvier (1829) suggested that Linnaeus and several subsequent workers had confused all the European mullet under the one name. The species known as M. cephalus has been consistently identified since Cuvier (1829) and by inference this can be assumed to be the principal of the several species confused by Linnaeus under that name.

Schultz (1949) has suggested that M. cephalus may not be a cosmopolitan species. Certainly published descriptions differ, but Thomson (1954a) studied specimens from the major areas of occurrence and could find no differences other than those attributable to changes in proportion with growth.

1.2.3 Subspecies No data

1.2.4 Standard common names, vernacular names

TABLE 1

STANDARD AND VERNACULAR NAMES

Country	Standard Common Name	Vernacular Name(s)
Australia	Sea mullet	Bully, mangrove, hard-gut, river, sand, poddy, bullnose, mullet.
Brazil	Tainhas	Paratys
Ceylon	Grey mullet	Manalei, Kitheya, Thelgodeya
China	Chi Yue	Wo tau (or Oo tow) Tzü
Egypt	Grey mullet	Bouri
France	Muge cephale	

Proportional measurements

TABLE 2

REGRESSION OF PROPORTIONAL LENGTHS ON TOTAL LENGTH
(after Kesteven 1942)

Proportional Measurement	No. of Fish	Length Range	Regression Equation	Correlation Coefficient
Head length	1129	3 - 58 cm.	$y = 0.172x + 0.216$	0.99
Pectoral length	395	25 - 46	$y = 0.163x + 0.69$	0.65
Pelvic length	396	25 - 46	$y = 0.290x - 0.18$	0.89
Dorsal length	392	25 - 46	$y = 0.396x - 0.41$	0.95
Anal length	1018	3 - 58	$y = 0.551x - 0.073$	1.00
Standard length	611	3 - 57	$y = 0.784x + 0.046$	1.00
Length to caudal fork (L.C.F.)	758	4 - 53	$y = 0.866x + 0.735$	0.99
Snout breadth	365	25 - 46	$y = 0.131x + 0.01$	0.89
Maximum breadth	383	25 - 46	$y = 0.255x - 1.90$	0.87

(x = total length; y = proportional measurement)

Country	Standard Common Name	Vernacular Name(s)
India	Grey mullet	Khringha, Kabala, Thirutha, Boi, Ainj
Italy	Cefalo	Volpina, Mecciato, Bidimbula
Japan	Bora	Ina, Ina Mabora, Todo
Malaya		Belanak
New Zealand	Grey mullet	Kanae
Pakistan	Minghach	Karil
Philippines	Aguas	Belanak, Saranara, Lumilog, Banak, Pili, Aligasin, Guisaa
Rumania	Laban	
South Africa	Haarder	Springer, Tulo, Tainha, flathead mullet
U.S.A.	Striped mullet	Black mullet, jumping mullet
U.S.S.R.	Loban	Cefal
Vietnam	Ca doi	

1.3 Morphology

1.3.1. External morphology

Two dorsal fins, ventral fins abdominal but not far back, opercles without spines. Teeth when present minute. Maxillary hidden when mouth closed. Interorbital width wide. A prominent adipose eyelid almost obscures the eye. Snout shorter than eye. Mandible with feebly double symphysial knob. Caudal deeply forked. (See also section 1.2.1.3)

TABLE 3

RATIO OF PROPORTIONAL MEASUREMENTS
(after Thomson 1954a)

Divisor	L.C.F.	Standard Length	Anal Length	Depth	Head Length	Origin of 1st Dorsal	Origin of 2nd Dorsal
Dividend							
Total length	1.06-1.13	1.22-1.33	1.76-1.89	4.32-5.51	4.24-5.54	2.27-2.79	1.48-1.75
Fork length		1.44-1.19	1.61-1.72	4.00-5.18	3.91-5.01	2.05-2.59	1.37-1.60

	Snout Length	Eye Length	Head Width	Interorbital Width	1st Dorsal Height	2nd Dorsal Height	Anal Height
Head length	3.93-5.84	3.45-4.31	1.33-1.52	1.78-2.27	1.73-2.26	1.67-2.10	1.54-2.00

	Depth of Peduncle	Depth at Pectoral	1st Dorsal Height	2nd Dorsal Height
Depth	2.18-2.80	1.03-1.28	1.57-2.05	1.52-2.29

	Fin Base				
	1st Dorsal	2nd Dorsal	Anal	Pectoral	Ventral
Fin height	1.04-2.58	1.12-1.54	1.18-1.47	2.00-3.23	1.88-2.35

Geographic variation: none evident. Sylva, Stearns and Tabb (1956) found significant differences in interorbital width and pectoral base length between mullet from various localities in Florida. However, they were unable to determine whether the differences were genotypic or phenotypic.

Changes with growth: the adipose eyelid is not apparent in sea mullet smaller than 5 cm L.C.F. Its relative mass increases with size. The angle from the corner of the mouth to the centre of the lower jaw is acute in small fish, becoming less so and finally obtuse in mature fish. Axillary scales increase in relative length with age. The ciliate teeth tend to be lost or submerged in the lip with age. Below 5 cm (Querimana stage) the anal fin has 2 spines and 9 rays; adults have 3 spines and 8 rays.

1.3.2 Cytomorphology no information

1.3.3 Protein specificity no information

2. DISTRIBUTION

2.1 Total area

M. cephalus is found in the coastal waters and estuaries of the tropical and subtropical zones of all seas (Table 4; Fig. 2).

TABLE 4

GEOGRAPHIC DISTRIBUTION OF M. CEPHALUS BY LETTER CODE IN APPENDIX I (Rosa 1962)

Abundant	Rare
PSE, INW, ISW,	ISEW, PSW,
ASE, ASW, ISE	ANE, ANW

Distribution is roughly between 42°N. and 42°S. Except for the Mediterranean and Black Seas this species does not appear to inhabit waters where the average monthly water temperature drops below 16°C or where the summer temperature fails to reach above 18°C.

M. cephalus frequently ascends rivers into the freshwater zone (Table 5). That the freshwater phase may not be obligatory is suggested by the mullet's presence for most or all of the year around riverless islands remote from the coast, such as the Abrolhos Islands in Western Australia (Thomson 1950) or the islands of the Great Barrier Reef (Stephenson and Grant 1954). To what extent the species is pelagic is unknown. It has certainly spread to remote islands such as the Hawaiian Islands and the Galapagos either by adult nomadism or by juvenile drift.

2.2 Differential distribution

2.2.1 Spawn, larvae and juveniles

Spawn: during autumn and early winter in surface waters over deep water towards the edge of the continental shelf (Arnold and Thompson 1958) or at least over deep water (Dekhnik 1953).

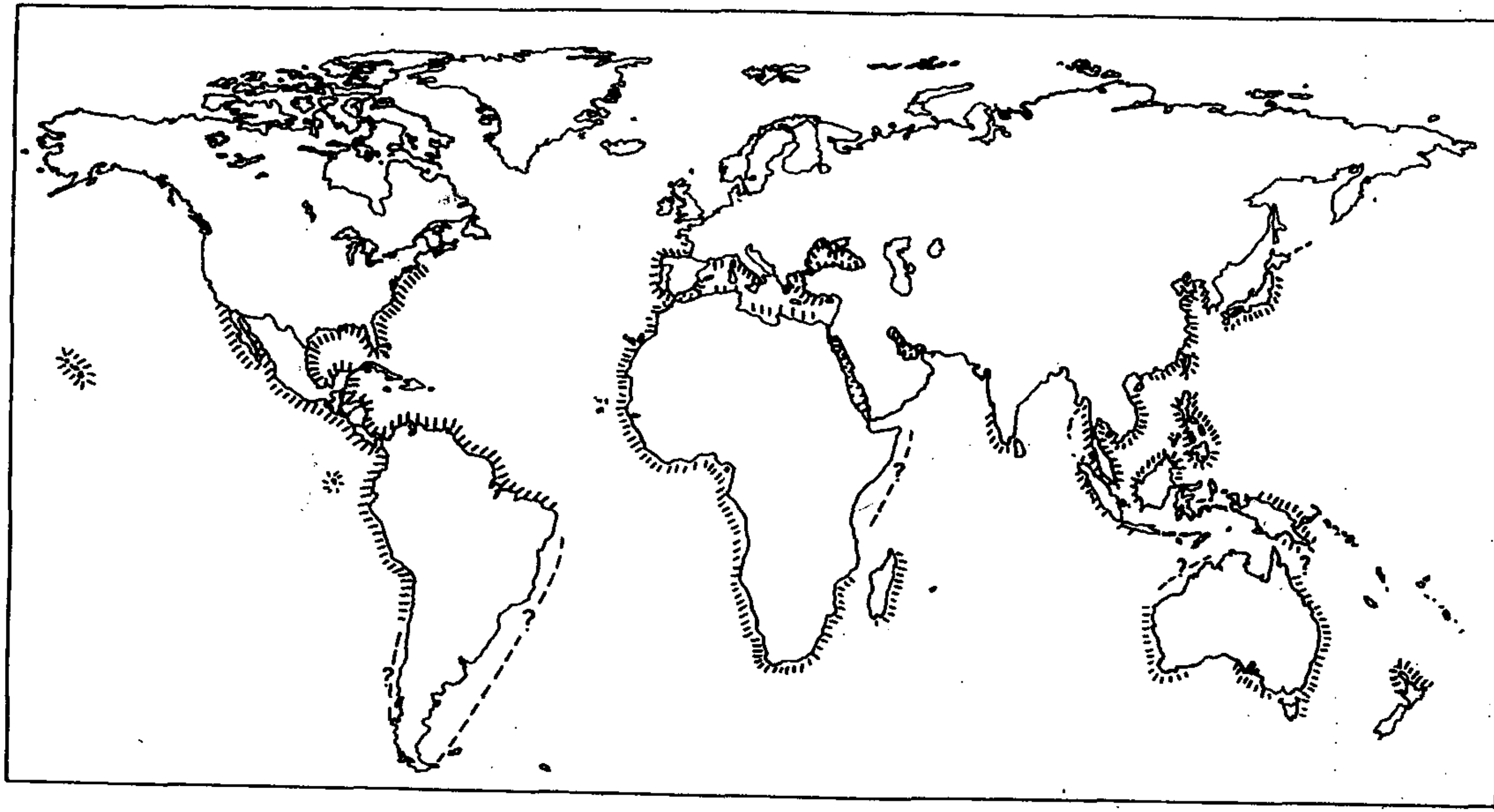

Fig. 2. Distribution of *M. cephalus*

Larvae: eggs and larvae drift from the spawning grounds with the prevailing currents until large enough to swim against tidal streams when they enter the estuaries at a size between 20 and 30 mm L.C.F. (Jacot 1920; Higgins 1928; Kesteven 1942; Broadhead 1953; Bromhall 1954; Hotta 1955), a size which is probably attained at 2 to 3 months after hatching according to Bromhall's curve of growth. Anderson (1958) has recorded still smaller M. cephalus on the beaches where the 100 fathom line comes close inshore.

Fry: the small fry make their way up the estuaries exploring the tidal creeks as they go. "Although some mullet fry reach the fresh waters within three months of entering the bay, this does not imply that all the fry make their way there. Schools remain scattered along the whole length of the line from bay mouth to fresh water. Lowered salinities certainly seem to attract the fry as every creek is a centre of concentration, the shallows remote from a creek mouth rarely being occupied by mullet of the 0+ group" (Thomson 1955).

Juveniles: the juvenile mullet inhabit the estuaries and lower freshwater zones, moving in small schools which may at times travel considerable distances within the river system. The older juveniles may migrate to sea and travel along the coast to other rivers, usually in mid-summer before the spawning migration of adults takes place (Kesteven 1953; Thomson 1955). Towards the edges of the species range young mullet may penetrate further than the adults. Earll (1887) and Higgins (1932) agree that juvenile mullet occur in New Jersey waters, but adults are found only in waters further south.

2.2.2 Adults

In the trophic phase adults are typically scattered in the freshwater zone of rivers, at least in Australia. There are records of M. cephalus from freshwater in other countries (Table 5), but there has been no suggestion that this is their regular habitat.

TABLE 5

RECORDS OF M. CEPHALUS FROM FRESHWATER

Country	Authority
Australia	Tenison-Woods (1882), Roughley (1916), Kesteven (1953), Thomson (1957a), Lake (1959)
U.S.A.	Hoxie (1884), Orcutt (1891), Baughman (1946), Riggs (1957), Miller (1958), Robinson (1959), Follett (1960), Springer and Woodburn (1960)
India	Spurgeon (1947)

M. cephalus is also found in areas where the salinity is above normal even up to 75‰ (Simmons 1957). There are indications of permanent aggregations of adult mullet in shallow seas (Thomson 1951; Stephenson and Grant 1954). There is some evidence that adult *M. cephalus* may occur well off shore: a few specimens were brought up in a trawl hauled at 180 fathoms (Howard, Marshall and Wimpenny 1955).

During the spawning migration the adults are found moving in schools along the beaches (Kesteven 1942).

Seasonal variation in areas of occurrence: Earll (1887) reported young mullet in New Jersey waters only in September and October and Smith (1898) recorded the same two months of sojourn in Woods Hole, Massachusetts. But Sumner *et al.* (1911) reported mullet at Woods Hole from "July to December, most commonly in the fall". North Carolina seems to be the furthest north on this coast that mullet are found all the year round, though even here large ones are taken only in autumn (Earll 1887).

2.3 Determinants of distribution

The lower limit of temperature controlling the natural distribution of the species seems to be between 16° and 18°C. *M. cephalus* failed to appear in San Diego Bay over several years when the mean annual temperature ranged from 14° to 17.8°C (Radovich 1961). This temperature limitation may explain why the species is less common in freshwaters in North America than in Australia.

Rheotactic or chemotropic responses have been suggested as the stimulus attracting mullet fry and older groups into rivers and tidal creeks (Arné 1938; Beadle 1946; Faouzi 1938).

The main foods (Section 3.42) of the species restrict it to shallow waters for feeding and presumably explain its abundance in estuaries and lagoons where such foods reach their greatest density.

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality

M. cephalus is heterosexual. No externally observable characters are known to distinguish males from females. Stenger (1959) has reported a condition of the immature gonad that suggests a state of intersexuality. Occasional individuals may be hermaphrodite (Kesteven 1942; Johnson 1954; Stenger 1959).

3.1.2 Maturity

The published estimates of size and age at first maturity vary. But apart from differences in interpretation of age-recording structures (cf. Jacot 1920; Hubbs 1921; Broadhead 1953) there is a rough correspondence between reported size at maturity and the local mean sea temperatures such that the youngest ages at maturity and smallest minimum sizes at maturity have been recorded from the warmer waters and the greatest size and age at first maturity from the coldest waters (Table 6).

TABLE 6

ESTIMATES OF SIZE AND AGE AT MATURITY

Area	Age M	Age F	Aging Method	Size at Maturity M	Size at Maturity F	Weight at Maturity g	Sea Temp.*	Authority
Florida (west)	3	3	scales	23-29	24-31	300-310	22-29	Broadhead 1953
Florida (east)	2	3	not stated	23.6	25.5		24-29	Stenger 1959
Florida (east)	1	1	scales	33	35		24-29	Jacot 1920
Florida (east)	2	2	scales	33	35		24-29	Hubbs 1921
Australia (east)	3	3	scales	30-34	30-34	290-390	16-22	Kesteven 1942
Australia (west)	3	3	scales	31-35	31-35	260-460	16-21	Thomson 1951
Egypt				31	33		15-23	Faouzi 1936
Sea of Marmora	5	5	otoliths	40	41.5		5-25	Erman 1959
Black Sea	6-7	6-7	not stated				5-23	Slastenenko 1956
Black Sea	6-8	6-8	not stated	31-37	31-37		5-23	Berg *et al.* 1949

* Temperatures from Table 1 Appendix 2 Rosa (1962) except for Sea of Marmora from Acara and Gozenalp (1959).

Less precisely Ommaney (1949) has recorded maturity as being reached between 30 and 40 cm. in the Mauritius region and Hotta (1955) recorded that all ripe males taken by him were less than 40 cm and ripe females more than 45 cm.

Arnold and Thompson (1958) took running ripe females from 25.8 cm and males from 24.0 cm upwards from a school apparently spawning in the Gulf of Mexico.

A detailed description of gonad stages which do not differ markedly from stages in other species is recorded in Kesteven (1942).

3.1.3 Mating

Promiscuous, each female attended by several males as she extrudes the ova (Arnold and Thompson 1958).

3.1.4 Fertilization

External, ova and sperm shed freely into the water (Arnold and Thompson 1958).

3.1.5 Gonads

Females from 40 - 45 cm in length have gonads weighing 350 - 400 g (Hotta 1955). The heaviest gonad weight recorded by Kesteven (1942, Fig. 8) was 230 g in a fish 58 cm long. Those of 40 - 45 cm fish were recorded by him as having gonad weights between 56 and 74 g. Kesteven (1942) gives equations to express the relationship between mature gonad weight and length of fish: for females $y = 6.6 + 0.09x$, and for males $y = 4.48 + 0.027x$ where $y = \frac{100 \times \text{gonad wt.}}{\text{total body wt.}}$ and x = total length. This gonad index varied from 1 to 7 for fish with undeveloped or developing gonads and from 11 to 12 for fish with ripe gonads (Kesteven 1942).

Fecundity: the number of eggs produced range from 1,275,000 to 2,781,000 (Kesteven 1942). Tosh (1903) recorded 2,000,000 to 2,500,000. In a single specimen 50 cm long Jacob and Krishnamurthi (1948) counted 1,320,000. One brood of eggs per year; some females spawn only in alternate years after first maturity (Thomson 1955).

3.1.6 Spawning

The spawning season extends over the late summer, autumn and early winter months, earlier in higher latitudes, later nearer the tropics (Table 7).

TABLE 7

SPAWNING SEASON OF MUGIL CEPHALUS

Area	Authority	Season	Peak
Florida	Broadhead and Mefford (1954)	October-February	November-January
Sea of Marmora	Erman (1959)	October	
Sicily	Belloc (1938)		September-January
Black Sea	Vodyanitskii and Kazanova (1954)	May-August	
Southern India	Jacob and Krishnamurthi (1948)	October-May	
East Australia	Kesteven (1942)	March-July	serially from south to north
West Australia	Thomson (1957c)	February-July	
Hong Kong	Bromhall (1954)	November-January +	December

+ By inference from post-larval collections. Other authors record from gonad examination.

The mid-summer spawning reported by Vodyanitskii and Kazanova (1954) suggests either misidentification or a different environment. Thomson (1957c) from macroscopic inspection concluded that M. cephalus produced only one set of ova per year, though the occurrence of partly spent ovaries suggested that shedding of the ova may spread over some period of time. Stenger (1959) from microscopic study stated that there is some evidence that Florida mullet spawn more than once in a season. Bromhall (1954) on the basis of size distribution of mullet fry considered there were two periods of spawning near Hong Kong, a lunar period apart. However, there was no evidence to suggest whether the same or different individuals participated in the two spawnings.

The observations by Dekhnik (1953) and by Arnold and Thompson (1938) suggest that spawning takes place at night.

The time of the mullet run along the sea beaches varies from year to year. Whether this also indicates variation in actual spawning time is unknown.

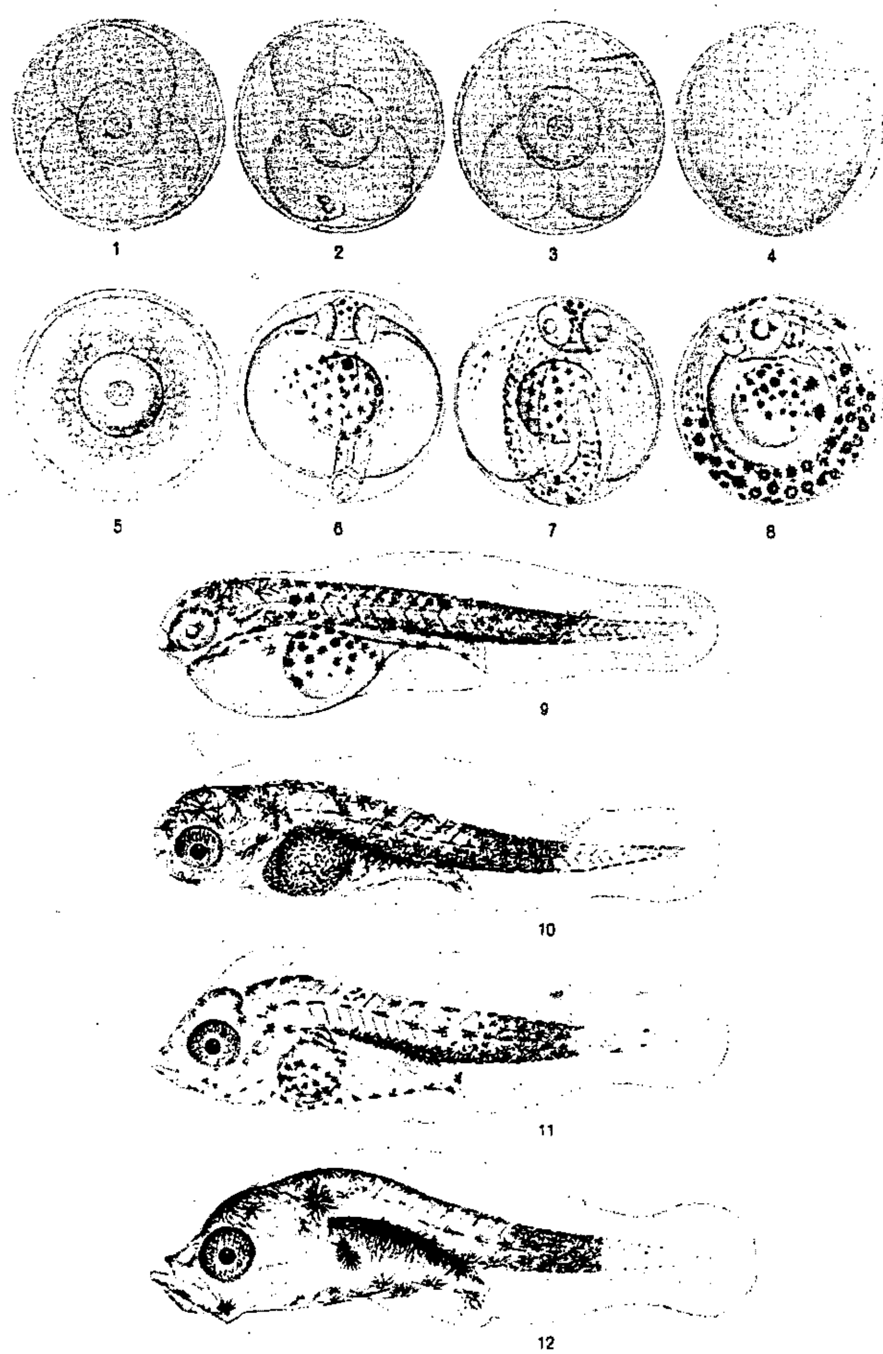

Fig. 3. Egg and larval stages of M. cephalus. (1) Egg 45 minutes after artificial fertilization, (2) egg 2 hours 30 minutes after, (3) egg 2 hours 45 minutes after, (4) egg, lateral view, 4 hours after, (5) egg, polar view, 4 hours after, (6) embryo 21½ hours after, (7) embryo 30 hours after, (8) embryo 46 hours after, (9) larva on hatching, 47 hours after fertilization, (10) larva third day after hatching, (11) larva fifth day after hatching, (12) larva eighth day after hatching.

After Sanzo 1936.

The two well authenticated instances of mullet spawning (Dekhnik 1953; Arnold and Thompson 1958) were at sea in surface waters but over deep water (50 fathoms in the Black Sea; 750 fathoms in the Gulf of Mexico). Hotta (1955) reported very small mullet larvae from the surface in water more than 100 fathoms deep.

By inference from behaviour other spawning places have been suggested: freshwater (Roughley 1916); in estuaries or tidal creeks (Smith 1935; Breder 1940; Jacob and Krishnamurthi 1948) in the surf zone (Kesteven 1942, 1954).

What was presumably the mating act has been described by Arnold and Thompson (1958). "From time to time.......... one or more groups of 3-6 fish would leave the school and swim around close to the surface in an erratic manner............. In a typical group the males, noticeably smaller and more slender, maintained position slightly behind what was ostensibly a female. Five or six times while they remained in view, one or more of the males would quickly move up beside or below the female, nudging and pressing against her abdomen with head and body. Often during this action the individuals thus engaged would quiver and cease swimming momentarily, sometimes rising to the surface. The unoccupied males swam rapidly back and forth in the immediate vicinity until they in turn behaved in a similar fashion".

Although males with running milt are not uncommon, females with running ripe gonads are seldom found in the estuaries or on the sea beaches. Most attempts at artificial fertilization, even those by Arnold and Thompson (1958) using fish netted from a spawning school, have been unsuccessful. Sanzo (1930, 1936) succeeded once in artificially fertilizing the eggs of a running ripe female. Belloc (1938) claimed a similar success.

3.1.7 Spawn

TABLE 8

CHARACTERISTICS OF THE OVUM OF M. CEPHALUS

Ovum Diameter mm	Diameter of Oil Globule mm	Buoyancy	Authority
0.65 - 0.75			Kawakami 1917
0.91 - 1.08			Nakano 1918
0.72	0.28	+ when shed - fertilized	Sanzo 1936
0.60 - 0.72	0.28		Vodyanitskii and Kazanova 1954
0.65 - 0.85			Hotta 1955
0.8	0.37	neutral	Nair 1957*

* From plankton tows; but might be from another species, e.g. Mugil troscheli

The ovum is transparent and spherical straw-coloured without any external sculpturing or marking, and is non-adhesive.

3.2 Pre-adult phase

3.2.1. Embryonic phase
(Figure 3 and Table 9)

TABLE 9

EMBRYONIC DEVELOPMENT OF M. CEPHALUS
(after Sanzo 1936)

Time Interval after Fertilization	Characteristic
1 hr	First stage of segmentation (unequal)
2 hr	Smaller blastomere divided; larger in initial stage of division
3 hr	Blastomere division complete
5 hr	The blastoderm disc covers a quarter of surface
20 hr	Pigment spots visible; optic capsules apparent
27 hr	Tail reaches 7/8 of way round egg to head
47 hr	Stellate chromatophores abundant
48 hr	Hatched

Nair (1957) describes a more rapid development which may be attributed to the warmer waters in his area or to possible misidentification (foot-note Table 8). He describes the pigment spots as visible in 9 hours (20 according to Sanzo) and hatching in 24 hours.

3.2.2 Larval phase

TABLE 10

DEVELOPMENT IN THE LARVAL PHASE
(after Sanzo 1936)

Age	Length	Characteristics
Hatching	2.4 mm (1.1 mm Nair)	Yolk oval from head to half length. Mouth not yet open, no paired fins, vertical fin-fold present; no branchial skeleton. Heart in embryonic position.
72 hours	2.6 mm (1.7 mm Nair)	Mouth is formed; heart rotated to final position; pectoral fin buds appear.
5 days	2.8 mm	Internal organs have become organized; the jaws are well-defined, the vitelline sac is much reduced.
8 days	3.1 mm	Snout better developed, vitelline sac completely disappeared, trunk pigmentation more intense.

Exact aging of post-larvae is unknown after 8 days except for one observation by Nair that at 28 days the larva is 10 mm long.

TABLE 11

DEVELOPMENT OF CHARACTERISTICS WITH GROWTH
(after Anderson 1958)

Size (T.L.)	Characteristics
4.00 mm	Caudal fin marked off by constrictions in primordial fold, thickening at side of future bases of dorsal fins, anal fin base thickened, pectoral lobes present, no ventrals, about 7 rays ventral to urostyle in tail fin.

Size (T.L.)	Characteristics
5.00 mm	Distinct caudal peduncle, urostyle flexed upwards, and all 14 principal rays are present, rays present in anal and dorsal fins, ventral fin lobes formed. Dorsal fold between dorsal fins.
8.00 mm	Four each of dorsal and ventral secondary caudal rays, dorsal rays well developed and finfold disappeared, last anal ray branched, 9 or 10 rays in pectoral fin, some rays in ventral.
11.00 mm	All caudal rays (14 principal, 15 secondary) present, last ray of second dorsal branched, all 16 or 17 rays in pectoral, and all 6 rays in ventral. Scales developing. Nostril becomes double.
13.00 mm	Caudal fork appearing, branching in last 2 rays of second dorsal and last 5 rays of anal. Scales on almost all body.
20 mm	Querimana stage, larva has 2 anal spines, large melanophores ventrally, all fin rays branching. Teeth in upper lip. Preorbital becomes serrated. Early larvae feed on plankton but by 30 mm are feeding on benthic algae and protista; at this size teeth are evident in the lower jaw.

3.2.3 Juvenile phase (adolescent)

The postlarva may be regarded as becoming a juvenile at about 50 mm when the third anal spine is formed from the anterior ray and the adipose eyelid starts to form. The caudal fin does not achieve its final form until about 110 mm but is already markedly forked.

3.3 Adult phase

3.3.1 Longevity

In the eastern Australian region the average life expectancy is probably about 3 years (Kesteven 1953; Thomson 1957). Fish up to 7 years have been recorded (Kesteven 1942; Thomson 1951). Fish larger than these have been recorded without age determination. Jacot (1920) recorded mullet 5 years old; these may have been 7 years old as there is some doubt on the validity of Jacot's age criteria (Section 3.4.3). Erdman (1959) has published a size for age table which accords well with Australian data and includes fish up to 9 years of age. Berg et al. (1949) record fish up to 13 years old, but at a length equivalent to size of 7 year old Australian fish. Hendricks (1961) records mullet up to 16 years in Salton Sea. From the von Bertalanffy equation quoted in Section 3.4.3 the probable maximum age can be calculated to lie between 11 and 21 years.

3.3.2 Hardiness

M. cephalus is found in waters whose salt content ranges from near zero to 75‰ (Simmons 1957). Temperature tolerance extends at least from 12° to 25° (Thomson 1951). Colder temperatures are recorded in parts of its range (e.g. Black Sea) but whether the fish actually experience this or retreat to more suitable waters is unknown. M. cephalus is known to tolerate the oil feed bleed water which pollutes the coastal creeks in some areas of the United States (Cole, Bennett and Miller 1958).

3.3.3 Competitors

Herbivorous, iliophagous and omnivorous marine animals compete with M. cephalus to a greater or less extent for food. Lists of species are referred to in Table 12. The relative importance of one particular kind of food (detritus) in the diet of M. cephalus and its competitors in a brackish lake with a soft mud substrate is reported by Darnell (1961). In this type of environment 77% by volume of the food of M. cephalus was detritus; in the case of its competitors it varied from 8% (Elops saurus and Cynoscion nebulosus) to 99% (juvenile Brevoortia patronus). The relative importance of detritus is less in other situations (Thomson 1954b).

TABLE 12

SOURCE LIST OF SPECIES COMPETING WITH M. CEPHALUS FOR FOOD

Competitors	Authority
Milkfish Chanos chanos	Hiatt 1944
Other Mugilidae	Thomson 1954b
Estuarine fish (20 spp.)	Thomson 1959
Fish (24 spp.) and crustacea (2 sp.)	Darnell 1961
Crustacea (5 spp.) Mollusca (2 sp.)	MacIntyre 1959

The relative abundance of competitors for food is hardly apparent in the published reports. In the Australian region commercial catch figures indicate that only other mugilids and the luderick, Girella tricuspidata, are important.

Any fishes or large invertebrate occupying part of the shallow waters inhabited by mullet could be regarded as competing for space. Thomson (1959) lists 103 species of fish from a marine-dominated coastal inlet, all of which would at some time be near mullet. But those of comparable size, existing in the same ecological zone, number only 6 (Table 13).

TABLE 13

MAIN COMPETITORS FOR SPACE
Lake Macquarie (Thomson 1959)

Luderick, Girella triscupidata	Telegalene mullet Myxus elongatus
Black bream, Mylio australis	Dusky flathead Planiprora fusca
Tarwhine Rhabdosargus sarba	Trumpeter whiting Sillago maculata

Of these only luderick and telegalene mullet are competitors for food.

3.3.4 Predators

The only recorded predators of the grey mullet are piscivorous fishes and certain diving birds (Table 14).

TABLE 14

PREDATORS OF MULLET

Species	Region	Authority
Fish		
Anguilla anguilla	Italy (fish farms)	Beadle (1946)
Anguilla australis	Australia	Thomson (1959)
Trudis bassensis	West Australia	Thomson (1957c)
Planiprora fusca	East Australia	Thomson (1959)
Sciaenops ocellata	Texas	Gunter (1945)
		Breuer (1957)
		Simmons (1957)

Species	Region	Authority
Cyncoscion nebulosus	Texas and Florida	Gunter (1945) Breuer (1957) Simmons (1957) Moody (1950)
Astroscopus ygraecum	Florida	Springer and Woodburn (1960)
Lepisosteus spatula	Texas and Louisiana	Gunter (1945) Darnell (1958)
Paralichthys lethostigma	Texas	Gunter (1945)
Lates calcarifer	India (fish farms)	Pillay (1948)
Serranus sp.	India (fish farms)	Pillay (1948)
Trichiurus haemela	India	Prabhu (1950)
Carcharhinus leucas	Louisiana	Darnell (1958)
Birds		
Phalacrocorax carbo	Australia	Serventy (1938) McNally (1957)
Phalacrocorax varius	West Australia	Serventy (1938)
Phalacrocorax sulcirostris	West Australia	Serventy (1938)
Anhinga novae-hollandiae	West Australia	Serventy (1939)
Pelicanus occidentalis	Florida	Hutton and Soganderes-Bernal (1959a)
Casmerodius albus	Florida	Hutton and Soganderes-Bernal (1959a)

Mullet do not predominate in the diet of any species, except in fish farms where little else is available. Predation is confined mostly to the small size groups, though 14 inch mullet were reported from Cynoscion stomachs by Breuer, and it is certain that mature mullet are taken during the spawning migration by sharks, at least in the Australian region, but records of shark stomachs inspected are wanting.

3.3.5 Parasites and diseases

The parasites known from M. cephalus are listed in Table 15. The life cycle is known only for Mesostephanus appendiculatoides and for Phagicola longa.

The cyathocotylid larvae of both are found in the gastropod *Cerithium muscarum*; the mullet is the intermediate host in both cases. The known definitive hosts of *M. appendiculatoides* are the brown pelican, *Pelicanus occidentalis carolinensis*, the Black-crowned Night Heron *Nycticorax nycticorax*, and the opposum, *Didelphis virginianus*. The definitive hosts of *P. longa* are the brown pelican and the American egret, *Casmerodius albus egretta* (Hutton and Sogandares-Bernal 1959b).

The intensity of infection in any individual is not recorded; the density of infection in the population has been recorded only by Hutton and Sogandares-Bernal (1959a) who found *M. appendiculatoides* in 60% of 1180 mullet examined in 1957, and 89% of 887 specimens in 1956. *P. longa* was present in 76% of the 1180 mullet examined in 1957.

Only the saprolegnian and the myxosporidian have been shown to cause mortality in the mullet.

TABLE 15

THE RECORDED PARASITES OF *M. CEPHALUS*

	Parasite	Region	Authority
Fungus	*Saprolegnia* sp.	Queensland, stagnant waters	Johnston (1917)
Myxosporidia	*Myxobolus exiguus*	Black Sea Sea of Azov	Petrushevski and Shulman (1958)
Actinomyces	?*Actinomyces* sp.	East Australia	Kesteven (1942)
Trematoda	*Microcotyle mugilis*	Mediterranean	Vogt (1878) Parona and Perugia (1890)
		Japan	Yamaguti (1938)
	Microcotyle pseudomugilis	Gulf of Mexico	Hargis (1956)
	Microcotyle macracantha	Gulf of California	Alexander (1954)
	Mesostephanus appendiculatoides	Florida	Hutton and Soganderes-Bernal (1959a and b)
	Phagicola longa	Florida	Hutton and Soganderes-Bernal (1959a)

	Parasite	Region	Authority
	Stephanostomum sp.	Florida	Hutton and Soganderes-Bernal (1960)
	Hysterolecitha elongata	North Carolina	Montes (1931)
	Dicrogaster sp.	Gulf of Mexico	Thatcher and Sparks (1958)
	Haplorchis taichui	Hawaii	Martin (1958)
	Stellantchionus falcatus	Hawaii	Martin (1958)
	Centrocestus formosanus	Hawaii	Martin (1958)
	Centrocaecum spiculigerum	Caspian Sea	Saidov (1953)
	Strictodora sawakinensis	Black Sea	Bykhovskaya and Petruslevski (1957)
	Parascotyle longa	Black Sea	Ciuerea (1931)
	Haploporus longicolum	Black Sea	Vlasenko (1932)
	Haploporus benedeni	Gulf of Naples	Palombi (1931)
	Heterophyes heterophyes	Egypt	Anonymous (1933)
	Heterophyes nocens	Japan	Asada (1928)
Cestoda	Otobothrium mugilis	East Australia	Hiscock (1954)
Acanthocephala	Neoechinorhynchus chilkaensis	India	Podder (1937)
	Atactorhynchus mugilis	Brazil	Machado (1951)
Copepoda	Lernanthropus shiskidai	Japan	Shino (1955)
	Clavellopsis longimanus	Gulf of Mexico	Bere (1936)
	Ergasulus lizae	Gulf of Mexico	Bere (1936)

Injuries and abnormalities

Wounded fish are sometime taken in commercial catches, particularly in hauls on the sea beaches, where they are usually attributed to shark attacks (Kesteven 1942). Popov (1930) has reported instances of shortening of the frontal bones and of the lower jaw in mullet from the Black Sea. 75% of old (14-16 years) mullet from the Salton Sea showed some abnormalities (Hendricks 1961). These were pathological, chiefly external and internal tumours, growths, and ulcers. Calculi in the mesonephric duct and edema were the two commonest conditions.

3.4 Nutrition and growth

3.4.1 Feeding

In the estuaries the mullet feed on the shallow banks during flood tide, whatever time of day this may be. The mullet "take in a quantity of sand and mud and after working it for some time between the pharyngeal bones they reject the roughest and most indigestible portion of it" (Gunther 1880c). Ghazzawi (1933) gave an essentially similar account of the feeding of mullet in an aquarium. The ejected sand and mud clouds the water and is used by fishermen to indicate a likely spot to net. The mullet also graze epontic diatoms and other algae from zostera and other sea-grasses (Wood 1959).

Postlarval and early juvenile mullet have been recorded as plankton feeders (Chacko 1949a, 1949b).

During the spawning migration little or no food is consumed (Kesteven 1942).

3.4.2 Food

M. cephalus feeds on microscopic organic matter, both living and detrital, on the bottom substrate or grazes on epiphytic diatoms, blue-green and filamentous green algae as well as other protista (review in Thomson 1954b). A proportion of sand is always mixed with the food and this is believed to assist in grinding the diatoms and other food in the muscular gizzard-like stomach. In particular localities the main food materials may differ (Table 16).

TABLE 16

PREPONDERANT FOOD ACCORDING TO LOCALITY

Food Item	Area	Authority
Diatoms, blue-green and green algae	Lake Macquarie, N.S.W.	Thomson (1959) Wood (1959)
Detritus	Lake Pontchartrain, Louisiana	Darnell (1958, 1961)
Small crustacea	Küçükcekmee estuary, Turkey	Erman (1959)
Foraminifera	Krusadai Is. India	Gnanamathu (1943)

TABLE 17

ANNUAL GROWTH RATE OF MUGIL CEPHALUS REPORTED FROM VARIOUS REGIONS

(L.C.F. at formation of annuli, in cm)

Area	Aging Method	Authority	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}
E. Australia	scales	Kesteven (1942)	14.9	23.1	31.7	39.7	47.7	53.7							
W. Australia	scales	Thomson (1951)	14.0	24.5	33.6	40.5	46.7	50.5	53.7						
Florida (east)	scales	Jacot (1920)	12-20	22-23											
Florida (west)	scales[1]	Broadhead (1958)	14.2	20.7	26.3										
Florida (west)	scales[2]	Broadhead (1958)	17.8	26.9	31.9	36.6									
Black Sea	not stated	Berg et al. (1949)[3]	10.8	16.3	20.8	24.8	28.1	31.2	34.3	37.3	40.4	43.0	45.6	47.4	52.6
Italy	not stated	Berg et al. (1949)[3]	18.0	29.0	38.0	42.0	44.0	45.0							
Italy	scales	Serbetis (1939)	22.0	35.3	47.5	49.0	52.7								
Italy	scales	Morovic (1954)	16.6	24.6	31.8	38.4	42.6	45.1							
Egypt	scales	Wimpenny (1932)	16.0	23.2											
Turkey	otoliths	Denizci (1958)	4.7	14.5	21.6	30.0	41.8	51.5							
Sea of Marmora	otoliths	Erman (1959)		17.1	25.3	33.3	42.6	50.3	55.0	59.0	62.0				
Bosphorus	otoliths	Erman (1959)	6.5	16.1	24.1	32.9	38.0								
Black Sea	scales	Alexandrova (1957)	22.0	33.0	48.0	56.0	60.0								
India (Chilka Lake)	scales	Devasundaram (1952)	30.0	42.0	55.0	64.0									

1 from Pensacola; fish from Apalachicola give similar figures
2 from Homosassa; fish from Cedar Keys give similar figures
3 quoting from an unacknowledged source but dated, Black Sea 1936-37; Mediterranean (Italy) 1939.

TABLE 18

ANNUAL INCREASE IN WEIGHT OF *MUGIL CEPHALUS* FROM VARIOUS REGIONS
(weight at formation of annuli to nearest g)

Area	Authority	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9	W_{10}	W_{11}	W_{12}
E. Australia	Kesteven (1942)	38	141	334	657	1211	1732						
W. Australia	Thomson (1951)	31	143	345	729	890							
Sea of Marmora	Erman (1959)		71	214	538	1133	1742	2370	3250	4000			
Bosphorus	Erman (1959)	≤5	64	190	532	736							
Black Sea	Berg *et al.* (1949)[1]	18	62	112	229	320	429	528	675	895	1050	1180	1290
Mediterranean	Berg *et al.* (1949)[1]	119	410	940	1300	1500	1600						
Italy	Serbetis (1939)	115	408	1028	1217	1525							

[1] quoting from an unacknowledged source but dated Black Sea 1936-37; Mediterranean (Italy) 1939.

3.4.3 Growth rate

There is lack of agreement in reported rates of growth. To some extent the differences may be due to differing interpretations of scale or otolith marks, but these could be real differences corresponding with environmental temperature (cf. Tables 6 and 17). Variation with locality occurs even along a relatively small stretch of coast (Broadhead 1953). In any one year there may be variation in growth rate between localities and in any locality variation from year to year (Kesteven 1942; Thomson 1951). In no case were the variations found in regional studies as great as those recorded between major geographical regions by different authorities (Table 17). Corresponding variations occur in estimates of increase in weight with age (Table 18). Growth in juveniles and adults is isometric (Kesteven 1942; Thomson 1951). From the data of Thomson (1951) Kesteven (personal communication) has calculated a von Bertalanffy equation

$$l_t = 68.869\ (1-e^{-0.21962(t+0.0332)})$$

In warm temperate and subtropical waters growth ceases in mid-winter (at 17° in West Australia) and is at its greatest in mid-summer (Thomson 1951; Broadhead 1958) (Table 19). Bromhall (1954) and Roule (1917) both calculated a growth rate of 10 mm per month for Querimana stage mullet.

TABLE 19

SEASONAL GROWTH RATE OF M. CEPHALUS

Area 1. Western Australia (Thomson 1951), 2. Clarence R. (Kesteven 1942), 3. Port Hacking (Kesteven 1942). Mean monthly increments in mm.

Age Group	Area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
I+	1	55	86	98	102	111	119	117	107	108	10	17	
	2	95		63	72	87	90	74				54	
	3	32	62		90			73			75	56	
II+	1	49	56	71	80	84	105	85	83	78	7	14	20
	2	52			56	52	65	47	40			30	38
	3		37			64			70		54	58	
III+	1	18	41	41	55		61		55	37	27	47	17
	2	43				42						28	52
	3		25			42					36	47	
IV+	1		33	34	30		33		31	30	42		
	2					30							
	3			47		32					36	29	
V+	1		31	35	26					32			
	3					32							
VI+	1				24					15	21		

The condition factor K estimated from the formula $K = W/0.01L^3$ ranges from 0.81 to 1.22 in individuals (Thomson 1951) and in sample means from 0.94 to 1.18 (Kesteven 1942). There are annual differences in the value of K in any particular area but during any continuous period there is only slight change in K amongst prespawning fish; however fish of spawning size exhibit a sharp drop in the value of K in mid-winter (spawning season) from a mean value of 1.12 to 0.96 in 4 weeks in an example quoted by Thomson (1951). However, in farm ponds Chow (1958a) has found the condition factor to remain fairly constant between 0.93 and 0.99 over the year. Yokota et al.(1961) record a value for K of 1.17 in postlarvae from 2 to 14 mm.

3.4.4 Metabolic rates no information

3.5 Behaviour

3.5.1 Migrations and local movements

Local movements consist largely of movement to and from the shallow flats as the tide rises and falls. There may be movements of some miles along an estuary (Thomson 1955), but there is little movement for much of the year and tagged fish may be recovered from the tagging site for long periods (Kesteven 1942; Thomson 1959; Broadhead and Mefford 1956).

A coastwise movement of older juveniles (II+ in Australian waters) may take place in summer prior to the spawning migration of the mature fish, usually after heavy rain has flooded the rivers (Roule 1915; Kesteven 1942, 1953; Thomson 1955).

The marked migration of mullet is their spawning run. As far as can be judged from tag returns individual fish may move only a few miles or up to 450 miles or so in the one season. Even after several seasons a similar scatter of distances is found amongst fish from the one source (Kesteven 1942; Thomson 1955). Although there is reason to believe (Section 3.1.6) that the spawning site may be offshore, much of the migration route lies along the beaches. The travelling schools may enter estuaries as they move along the coast but usually leave on the following tide. The migration seems to be made against the prevailing coastal current, that is northwards on both the east (Kesteven 1942) and west (Thomson 1951) coasts of Australia, and southward on the east coast of the U.S.A., but in the Gulf where currents are slight there is less obvious movement coastwise (Broadhead and Mefford 1956). Tagging in Australia has not revealed any return migration, the post-spawning fish that have moved north being recovered in rivers to the north of the original source (Kesteven 1953), but there is some indication of a return movement in Florida waters (Broadhead and Mefford 1956).

The migration starts earlier in cooler waters and proceeds river by river along the coast. As autumn approaches, schools gather in the estuaries which they leave during strong offshore winds (Thomson 1955; Anonymous 1951) or stormy periods (Kunstler 1904). Kunstler did not comment on wind direction.

The timing of migration varies from one year to another, sometimes by as much as two months. An individual fish may not participate in the spawning migration every year after maturity (Kesteven 1953; Thomson 1955).

3.5.2 Schooling

Mature mullet in the trophic phase tend to be scattered or in small schools of a few individuals (Kesteven 1942). Younger fish tend to be aggregated in schools of moderate size, which tend to amalgamate into larger schools as maturity and the spawning migration approach. Once past the fry stage, mullet are schooled up only while not feeding. During feeding the school breaks up and the individuals scatter over a limited area of the feeding ground. They retire from the feeding areas as the tide falls, or if they are alarmed the fish school up once more. Tagging suggests that although there may be some interchange of individuals between schools there is some prolonged association of the individuals in the one school (Thomson 1955). Non-migrating schools usually consist of one or two age groups only.

Ozaki (1951) has shown that even two mullet placed together in the light tend to aggregate together. Horstmann (1959) showed that schooling was a reaction to visual stimulus.

3.5.3 Responses to stimuli

There has been almost no experimental work on the responses of mullet to environmental stimuli. It is inferred from field observation that there is a positive rheotropic (or possibly chemotropic) response in the young fish, with a negative rheotropic reaction in mature fish with ripening gonads (Arné 1938; Faouzi 1938; Beadle 1946).

Kuthalingam (1959) has shown that *M. cephalus* fry from 1.1-7.2 cm in length acclimated in water of 32°-34°C showed a preference for water at 29°-32°C with the optimum selection at 30°C.

4. POPULATION

4.1 Structure

4.1.1 Sex ratio

TABLE 20

SEX RATIOS OF M. CEPHALUS POPULATIONS

Region	% Male	% Female	Number in sample	Authority
East Australia	63.5	36.5	3107	Kesteven (1942)
Bosphorus and Sea of Marmora	43.0	57.0	758	Erman (1959)

Kesteven (1942) remarked that although the total sample gave the proportion shown in Table 20 in any individual school sampled, either sex could predominate, though there was no evidence of total segregation. In a sample of very old (13-16 year) mullet, Hendricks (1961) reported 75% males.

4.1.2 Age composition

There are no records of the age composition of any stock or population as a whole. Age composition records of commercial catch are shown in Table 21.

TABLE 21

AGE DISTRIBUTION OF THE CATCH OF M. CEPHALUS
(%)

Area	O+	I+	II+	III+	IV+	V+	VI+ & older	Authority
East Australia	1.2	11.7	37.9	33.6	12.2	3.2	0.2	Kesteven 1942 (Table 7)
East Australia		22.3	41.4	24.2	9.5	1.6	1.0	Kesteven 1942 (Table 8)

Area	O+	I+	II+	III+	IV+	V+	VI+ & older	Authority
East Australia		29.6	40.9	23.8	5.3	0.3	0.1	Kesteven 1953 (Table 5)
West Australia		6.0	92.0	2.0[1]				Thomson 1951 (Fig.10) (estuaries)
West Australia			5.0	95.0[1]				Thomson 1951 (Fig.10) (sea beaches)
Sea of Marmora			11.4	37.9	22.2	21.8	5.3 1.4	Erman 1959 (Table 1)
Bosphorus		6.8	47.8	27.6	13.0	4.8		Erman 1959 (Table 2)

[1] This category contains III+ and older fish, though most were III+

The measurements recorded by Kesteven (1953) and by Thomson (1951) are from catches made by commercial fishermen. Those recorded by Kesteven (1942) include experimental hauls. Erman (1959) does not explain the method of capture of the samples measured by him. Older age groups (V+ and older) are represented in the catch almost solely in the migration season, March to May (Australia, Kesteven (1953) Tables 5B to 5E). The age at first capture is related to the legal minimum length, where such a provision exists (Table 22).

TABLE 22

AGE AT FIRST ENTRY INTO THE FISHERY AND THE LEGAL MINIMUM

Area	Age at first capture	Legal Length[1]	Authority
East Australia	late II+ to early III+	12"	Kesteven 1942
West Australia	a few I+ mostly II+	10¼"	Thomson 1950
Florida (west)	late I+ or early II+	10½"	Broadhead 1953

[1] These are the legal minima in force at the time the quoted studies were made. Present minima may differ (Section 5.5).

The maximum age recorded in Australian waters is nine years. Berg et al. (1949) record mullet of 13 years from the Black Sea (See Section 3.3.1).

Variation in the proportions of II+, III+ and IV+ and older fish in the catch month by month has been shown by Thomson (1953) (Tables 10 and 11). These show that II+ mullet dominated the New South Wales catch from 1939 to 1949 except in late summer to early winter when the III+ group dominated. IV+ and older fish seldom provided more than 3 to 12% of the catch even in the migration period. In Queensland III+ fish predominated, with II+ fish being only a small proportion of the catch in mid-winter, a period when IV+ and older fish made a significant contribution to the catch (22 to 42%).

4.1.3 Size composition

No records exist of the length composition of any stock or population as a whole; Kesteven (1942, Tables 5B - 5G) gives month-by-month frequency distributions of the marketed mullet catch. The important points are listed in Table 23.

TABLE 23

MODAL AND SIZE RANGES OF MULLET
(from Kesteven 1942)
(cm L.C.F.)

Area	Range in Modal size	Size range in Trophic phase	Size range in Migratory phase
Eastern Australia	28 - 33	21 - 42	22 - 54
Western Australia	21 - 24	20 - 44	20 - 52

Some other data which are not separated on a monthly or seasonal basis are reviewed in Table 24.

TABLE 24

SIZE RANGE OF MULLET IN COMMERCIAL CATCHES

Area	Authority	Modal Size	Size range
North-west Florida	Broadhead and Mefford (1956)	26.5	16 - 41
Mid-west Florida	Broadhead and Mefford (1956)	29.5	22 - 43
East Florida	Broadhead and Mefford (1956)	29.5	18 - 43
New South Wales	Thomson (1953)	27 - 29	20 - 60
Queensland	Thomson (1953)	32	20 - 50

Erman (1959) has given separate length-frequency graphs for males and females in which the only significant difference is the preponderance of females amongst fish larger than 45 cm. These were not market samples. The size at which mullet are first liable to capture in the various fisheries is shown by the lower figure in the size range column of Tables 22 and 23.

Size at maturity: see Section 3.1.2

Maximum size: Hendricks (1961) has recorded a female 62.2 cm and a male 59.9 cm from the Salton Sea (see Section 3.4.3)

Length-weight relation:

TABLE 25

FORMULA FOR LENGTH-WEIGHT RELATION

Authority	Area	Habitat	Formula
Chow (1958a)	Hong Kong	Fish-ponds	$W = 0.00808\ L^{3.025}$
Hotta (1955)	Kaba Is. Japan	Neritic zone	$W = 0.02817\ L^{2.9755}$

Although based on pond-reared fish Chow's length-weight curve is in accord with those of Kesteven (1942) and Thomson (1951). Hotta's formula does not seem to be in accord with the relation shown in his Figure 3, though his fish are heavier per unit of length than those of Chow, Kesteven or Thomson.

4.2 Abundance and density

4.2.1 Average abundance

The only published estimate of population size is that of Thomson (1959) for Lake Macquarie, a marine-dominated coastal inlet (Table 26).

TABLE 26

POPULATION ESTIMATE OF MULLET IN LAKE MACQUARIE, N.S.W.
Area 42 square miles

Area of feeding zone 17 square miles. Confidence limits by method of Delury (1951)

Numbers	(Confidence Limits) Lower Limit	Upper Limit	Weight (lb)	Method
2,693,000	1,152,000	6,248,000	1,777,400	Petersen tagging
2,540,000	1,439,000	16,123,000	1,676,400	Schnabel tagging

4.2.2 Changes in abundance

Thomson (1959) has indicated a change in abundance of mullet in Lake Macquarie as a result of hydrological conditions which are believed to have affected food supplies.

Kesteven (1942) suggested that fishing of Australian stocks may have caused some decline in abundance, but alternative explanations of the trend in catch have been offered (Thomson 1953).

4.2.3 Average density

The population estimate of mullet in Lake Macquarie (Thomson 1959) suggests a density of 62 lb or 95 fish of legal size per acre.

4.2.4 Changes in density

The annual variation in the catch per man and the catch per net for the fishing districts of New South Wales have been recorded by Thomson (1953) and the catch per man and catch per 10 man-hours for various estuaries in Western Australia by Thomson (1950). There is considerable variation both between estuaries and between seasons for any one district. There is also considerable seasonal variation in availability (Thomson 1950, Figs 3-9; Thomson 1953, Figs 6-8).

4.3 Natality and recruitment

4.3.1 Reproduction rate no information

4.3.2 Factors affecting reproduction no information

4.3.3 Recruitment

Dannevig (1907) has suggested that if off-shore winds prevail immediately after spawning there will be loss of eggs and young to sea with the surface drift with subsequent poor recruitment to the estuaries. No quantitative information is available.

4.4 Mortality and morbidity

4.4.1 Mortality rates

TABLE 27

CALCULATED MORTALITY COEFFICIENTS OF MULLET

Area	Fishing Mortality	Natural Mortality	Total Mortality	Method	Authority
Lake Macquarie	0.20	0.33	0.53	short-term tagging	Thomson (1959)
Lake Macquarie	0.003	0.58	0.583	long-term tagging	Thomson (1959)
North-west Florida			0.995	short-term tagging	Broadhead and Mefford (1956)
North-west Florida			0.79	market sizes	Broadhead (1953)
North-west Florida	0.50	0.29		short-term tagging	Broadhead (1953)

4.4.2 Factors causing or affecting mortality

The role of predators has been referred to in Section 3.3.4. No other information.

4.4.3 Factors affecting morbidity

For parasites see Section 3.3.5. Myxobolus exiguus is reported as the cause of death in the Black Sea and Sea of Azov (Petrushevski and Shulman 1958).

4.4.4 Relation of morbidity to mortality rate no information

4.5 Dynamics of population (as a whole) no information

4.6 The population in the community and the ecosystem

"The major part of the life of mullet (M. cephalus) is spent in the coastal lakes, rivers and bays in fresh and brackish waters. A smaller portion of its life is spent in truly marine water during various coastwise migrations." (Kesteven 1942).

Salinity range : trace to 75‰ (Simmons 1957)

Temperature range : 12° to 25° (Thomson 1951)

Trophic habitat : estuarine mud-flats, river shallows with plant growth: retreating to deeper channels when resting or alarmed.

Breeding habitat : surface waters over deep waters (Section 2.2.1).

TABLE 28

THE NUMBER OF SPECIES RECORDED FROM THE COMMUNITY INCLUDING M. CEPHALUS

Number of species of Fish	Invertebrate	Plant	Place	Character	Authority
102	22[1]	77[3]	L. Macquarie	marine-brackish	Thomson (1959), Wood (1959), MacIntyre (1959)
205			Tampa Bay	marine-brackish	Springer and Woodburn (1960)
35[1]	15[1]	11[1,4]	L.Pontchartrain	marine-brackish	Darnell (1958, 1961)
46		51[2]	Caloosahatchee R.	marine-brackish	Phillips and Springer (1960)

1 common species only.
2 5 sea-grasses, 14 higher algae, 58 diatoms.
3 6 sea-grasses, 45 higher algae.
4 2 sea-grasses, 4 higher algae, 4 diatoms, 1 blue-green.

Springer and Woodburn (1960) record M. cephalus as very abundant in 5 of the 8 habitats identified by them and occurring in 2 of the other 3. At least 16 other species of fish are listed as abundant from some of the same habitats. Their relative abundance is not specified.

Mullet are herbivorous and iliophagous (Section 3.4.2), they are preyed on by piscivorous fish but in quantity only in unusual habitats such as fish ponds (Section 3.3.4).

5. EXPLOITATION

5.1 Fishing equipment

5.1.1 Gears

The gears used to catch mullet in various parts of the world range from spears and cast nets to beach seines, set nets, and shore-line traps with many local modifications to suit local conditions (Table 29).

In parts of Florida use is made of light, not as an attractant, but as a scare, to direct fish into set nets. A device called a flambeau is made by wiring a large bundle of rags or burlap to the end of a pole, soaking it in gasoline and igniting it. Burning gasoline drips down and spreads over the water scaring mullet from its vicinity (Sutton 1950).

5.1.2 Boats

In almost all fisheries the boats used for setting nets are small net-dinghies, oar-powered and from 9 to 15 feet long. These may be towed to the fishing site by launch. In Florida "speed setting" may take place directly from the stern of a fast-moving launch or from a skiff towed directly astern.

5.2 Fishing areas

5.2.1 General geographic distribution

See Section 2.1. *M. cephalus* is fished wherever it appears.

5.2.2 Geographic ranges

M. cephalus is generally regarded as being confined to the continental shelf region. Nevertheless its distribution is world-wide and it is found on the coasts of oceanic islands, so it would appear that there is some movement across the deep sea, though whether this is due to active movement of adults or aimless drift of young is unknown.

Mullet are found in the drainage basins of all rivers discharging along the coast-lines where they occur. The areas of greatest abundance are given in Table 30.

TABLE 29

TYPE OF GEAR USED TO TAKE MULLET

Gear type	Region	Local name	Length	Mesh	Material	Authority
Modified purse-seine	Seto Is. and Ise-Makure Bay	Chadaka-ami	500-550 m			Anonymous (1958)
Trammel	Florida			inner 2-4 in. outer 8-12 in.	cotton,6 or 15 nylon	Siebenaler(1955)
	Coastal Japan	trinal gill			synthetic	Anonymous (1958)
	Palestine	tihweek				Craig-Bennett (1938)
Gill-net	Australia	mesh-nets		2-3½ in.	linen or nylon	McInnes (1950)
	Florida	turn-around gill	65-130 m	2¼-4½ in.	linen 25/3, nylon 10, 139 or 208,cotton 30/6	Siebenaler(1955)
	Florida	winding gill	85-130 m	2 7/8 - 3¼ in.	nylon 208	Siebenaler(1955)
	Japan	Maki Sashi-ami	500 m	6.5 - 8 cm	hemp	Anonymous (1958)
	India	Noo vala	350-500 m	1 in.	cotton 20s.	John (1955)
	Philippines	Pante	150-200 m			Rasalan (1953)
	Spain	Saltade				Cabo (1959)
Beach seine	Australia			wings 1 7/8-3 1/8 in. bunt 1¼ - 2¾ in.	cotton linen	McInnes (1950)
	Florida	Apalachicola seine	400-600 m	1½ - 2 in.	cotton 12 or 15	Siebenaler(1955)
	Japan	Jikogi-ami or Jibiki-ami	300-400 m			Anonymous (1958)
	India	Nerya vala Thelinga vala	70 m 120 m	¼ in. - ½ in.	cotton 20s. cotton 20s.	John (1955) John (1955)

	Philippines	Sinsoro	130 m		cotton or hemp	Rasalan (1953)
	Spain	Baliche				Cabo (1959)
Staked net	Australia (Queensland)			- 3 in.	cotton	
	Japan	Chochin-ami				Anonymous (1958)
		Tateboshi-ami				Anonymous (1958)
	India		6-10 m	½ in.		John (1955)
Shore-trap	Australia (Queensland)				wire net	
	Philippines	Pahuba			bamboo	Rasalan (1953)
Barrage trap	Italy	Haioneri				Angelis (1960)
	Spain	Encanizadas				Cabo (1959)
	France	Bordigios				Angelis (1960)
Dip-net	Japan	Fumiage-ami	10 m			Anonymous (1958)
	Philippines	Tagpaw				Acosta (1953)
Cast-net	U.S.A. (Gulf States)		4-6 m	1½ - 3 in.	linen 35/3	Tressler (1951)
	Japan	Toami	2-5 m	1 - 5 cm	silk, linen or cotton	Anonymous (1958)
	India		3-5 m			John (1955)
	Philippines	Data				Acosta (1953)
	Palestine					Craig-Bennett (1938)

TABLE 30

AREAS OF GREATEST ABUNDANCE OF MULLET, REFERRED TO THE BIOGEOGRAPHIC REGIONS IN APPENDIX II OF ROSA (1962)

Country	Area	Biogeographic code	
Europe	Mediterranean	5.51	
	Black Sea	5.52	
North America	Florida	5.31	
	Gulf of Mexico	5.64	
	Gulf of California	4.64	
Japan	South-east coast	4.61	
Philippines		4.61	
China	Central to north	4.31	
South Africa		1.54	
India	Travancore-Cochin	1.16	
Australia	South	1.62	4.93

Greatest abundance appears to be in seas where water temperature does not drop below 16°C in winter or 18°C in summer, but why the species should be common in some tropical seas (1.16) but not in others is not apparent.

5.2.3 Depth ranges

Generally regarded as surface fish in shallow waters, but there is one record of fish taken in a trawl which had been working at 180 fathoms (Howard, Marshall and Wimpenny 1955).

5.2.4 Conditions of the grounds

Estuarine grounds are subject to much change. Siltation is continuous, but also in Australia and probably elsewhere many of the shallow feeding grounds are being eliminated by reclamation projects (Thomson 1954b). Industrial pollution may also eliminate some estuarine grounds as in Port Jackson, Australia.

5.3 Fishing seasons

5.3.1 General pattern of seasons

The general pattern of the fishing season is similar in most parts of the world. Some fishing takes place in the estuaries and coastal inlets at all times of the year, but increased catches are made in autumn and winter as the mullet merge into the migratory schools.

5.3.2 Dates of beginning, peak and end of season

Since the season is continuous, information is given in Table 31 on the peak season only.

TABLE 31

DATE OF PEAK SEASON OF MULLET FISHERY

Area	Date	Authority
Southern New South Wales	February-March	Kesteven 1942
Central New South Wales	March-April	Thomson 1953
Northern New South Wales	April-May	Thomson 1953
Queensland	May	Thomson 1953
Turkey	November-March	Erman 1959
Biscayne Bay, Florida	September	Siebenaler 1953
North Carolina	October-November	Taylor 1951

5.3.3 Variation in date or duration of season

Heavy rains may disrupt the mullet schools; Thomson (1953) has reported such a situation in Queensland in 1951, when the catches were better in February than later in the season. When the catch from an individual river system is considered rather than that from a larger area, the variation is greater e.g. the Clarence R. New South Wales, where the peak month varied over a 10 year period from January to May (Thomson 1953).

Siebenaler (1953) reported a very low catch from the Biscayne Bay area from January to March as a result not of availability, but of transfer of the fleet to the seasonal mackerel fishery in those months.

5.4 Fishing operations and results

5.4.1 Effort and intensity

It is difficult to obtain a satisfactory measure of effort in an estuarine fishery. The few attempts have made use of the number of men, number of boats or number of men-hours.

The landings of mullet per unit of effort in Australian waters have been recorded for short periods by Thomson (1950, 1953). For the most and least productive estuaries in New South Wales and Western Australia the following are recorded (Table 32).

TABLE 32

RANGE OF CATCH PER UNIT OF SPECIFIED EFFORT IN THE MOST AND LEAST PRODUCTIVE ESTUARIES

	N.S.W. lb/man/year 1949-1950		W.A. lb/man/year 1941-1946
Best	8745 - 21,884	Best	2318 - 13,601
Worst	336 - 2349	Worst	6 - 138
	lb/net/year		lb/10 man-hours
Best	8112 - 24,449	Best	67.6 - 97.9
Worst	673 - 3212	Worst	0.4 - 6.4

The catches of mullet per unit of effort will not differ very much from these, though some undersized fish may be returned to the water.

The nature of the fishery does not lend itself to computation of the effort per unit area. In Lake Macquarie under present management measures the effort in terms of man-power has varied from 0.5 - 1 man per square mile; in a previous phase when part-time as well as full-time fishermen were allowed to operate (Thomson 1959) the number varied from 1 - 2 men per square mile; in a still earlier phase before competition from trawled fish became great and before a good proportion of the lake was closed to net fishing the effort varied from 1.5 to 3.5 men per square mile.

Fishing intensity is likewise difficult to compute in this type of fishery. In New South Wales, the number of men fishing on mullet between 1939 and 1949 varied from 1000 to 1900, and the number of nets in use from 650 to 1220 (Thomson 1953).

The causes of variation in fishing effort and intensity in New South Wales waters have included reduction in manpower during the war years, the effect of management measures such as that enforced in 1949 restricting fishing licenses to full-time fishermen, and the effect of competition from trawled and imported fish (Thomson 1953).

5.4.2 Selectivity

Broadhead (1953) has published selection curves for trammels, gill nets and seines used in Florida (Table 33).

TABLE 33

RANGE AND MODAL SIZE OF CATCH IN NETS OF VARIOUS TYPES AND MESHES (from Figures 6, 7, 8 of Broadhead 1953)

Net mesh (inches)	Range of size of catch (cm)	Modal size (cm)
Trammels		
2¼"	16.5 - 38.5	22.5
2½"	20.5 - 34.5	24.5
2 5/8"	23.5 - 39.5	27.5
2¾"	23.5 - 45.5	29.5
3"	25.5 - 39.5	29.5
3¼"	26.5 - 42.5	31.5
Gill nets		
2½"	21.5 - 33.5	26.5
2 5/8"	22.5 - 33.5	26.5
2¾"	23.5 - 39.5	29.5
2 7/8"	24.5 - 38.5	27.5
3"	25.5 - 39.5	27.5
3 3/8"	26.5 - 38.5	29.5
Seine		
2"	16.5 - 42.5	28.5
2¼"	19.5 - 38.5	26.5

5.4.3 Catches

TABLE 34

MEAN ANNUAL YIELDS OF MULLET IN FLORIDA AND AUSTRALIA WITH COEFFICIENT OF VARIATION (V)

(Catch data from Idyll 1950 and Broadhead 1953 for Florida from annual reports of State Departments for Australia)

Region	Period	Mean yield (lb)	V (%)
North-west Florida	1941-1951	6,136,699	32.9
Florida	1933-1951	34,527,320	25.6
Western Australia	1941-1960	541,814	41.8
Victoria	1941-1960	55,914	99.6
New South Wales	1941-1960	6,160,898	20.8
Queensland	1941-1960	3,962,955	13.9
East Australia	1941-1960	9,981,477	13.8
Australia	1941-1960	10,503,721	11.9

Annual yields from individual fishing grounds are not available, though the New South Wales catch can be subdivided into fishing districts (Table 35).

TABLE 35

MEAN ANNUAL YIELDS AND COEFFICIENT OF VARIATION OF THE MULLET CATCH (lb) FOR FISHING DISTRICTS IN NEW SOUTH WALES 1941-1950 (from Thomson 1953)

District	Mean yield	V
Tweed R.	510,624	31.3
Richmond R.	386,323	19.6
Clarence R.	2,216,207	18.3
Nambucca R.	182,341	44.9
Pt Macquarie	870,915	13.4
Manning R.	260,589	51.2
Wallis Lake	615,868	23.6
Pt Stephens	412,671	25.4
Hunter R.	48,172	103.0
Lake Macquarie	193,064	56.9
Tuggerah Lakes	313,177	49.2
Brisbane Water	24,809	77.2

6. PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.1.1 Limitation or reduction of total catch

Limitation on efficiency. No recorded limitations other than those listed under 6.1.2 which actually also affect efficiency.

Limitation on number of fishing units. No direct limitations are recorded, but the number of fishermen has been reduced in the State of New South Wales, Australia, by application of a law restricting the issue of netting licenses to full-time fishermen.

Quota limitations None recorded

6.1.2 Protection of portions of population

Closed areas - Australia. Net fishing is barred above tidal limits. In many inlets and estuaries portions are closed to net fishing either as nursery areas, to prevent disruption to schools as they enter or leave the entrances, or because it is politically expedient to reserve some areas for amateur fishermen.

Closed seasons - Australia. The State of Victoria has a closed season in several tidal areas, not to protect mullet but to prevent net fishing during the tourist angling season.

U.S.A. Prior to 1957 Florida enforced a 40-day closed season from December 10 to January 20, during what was believed to be the spawning season. This no longer applies (Ellis 1959).

Limitations on size or efficiency of gear - Australia. Regulations differ in each State. A legal minimum mesh is declared which is designed to select only certain sizes of mullet, and this method of protection is reinforced by declaring minimum legal lengths (Table 36).

TABLE 36

LEGAL LENGTH OF MULLET AND LEGAL SIZE OF MESH OF NETS IN AUSTRALIA (IN INCHES) AS AT NOVEMBER 1, 1961

	N.S.W.	Queensland	Victoria	Tasmania	South Aust.	West Aust.
Total length	13	12	10	8	7	9½
Mesh size (gill net)	3 1/8	3		2	1 7/8	2½
Mesh size	(hauling net)					
wings	3 1/8	3			1 7/8	3
bunt	2-2½	2¾		1¼	1¼	2

Permissible lengths of net vary not only between States but within States ccording to departmental assessment of requirements in each water system.

Israel. A minimum legal length of grey mullet is declared (Gideon 1953).

Restrictions based on sex or condition of fish. None recorded.

Restrictions on use of fish. None recorded.

6.2 Control or alteration of physical features of the environment

6.2.1 Regulation of flow

The flow of the freshwater sections of many Australian rivers are conrolled or modified by the building of dams and weirs. The effect of this on he mullet populations of this zone has not been studied.

6.2.2 Control of water levels

This also is achieved by the building of dams and control of the flow from hem, the effect has not been assessed.

6.2.3 Control of erosion and silting

This is achieved on some waterways by flood control using dams. No assessient of the effect on mullet stocks has been made.

6.2.4 Fishways

Several of the dams and weirs on the lower reaches of Queensland rivers ιave fishways attached which are known to be used by mullet.

6.2.5 Fish screens No information

6.2.6 Improvement of spawning grounds Inapplicable

6.2.7 Habitat improvement - Australia Negative

In many instances feeding habitats have been reduced by reclamation of arge areas of shallow mud flat. Siltation has also altered the character of ιany estuarine substrates, usually resulting in decreased food production.

6.3 Control or alteration of chemical features of the environment

6.3.1 Water pollution control - Australia

Laws exist but are not always enforced to prevent industrial and household ›ollution of estuaries.

6.3.2 Salinity control Lacking

6.3.3 Artificial fertilization of waters Lacking

6.4 Control or alteration of the biological features of the environment

6.4.1 Control of aquatic vegetation Lacking

6.4.2 Introduction of fish foods Lacking

6.4.3 Control of parasites and diseases Lacking

6.4.4 Control of predation and competition Lacking

6.4.5 Population manipulation Lacking except for effects listed under 6.1

6.5 Artificial stocking

6.5.1 Maintenance stocking Lake Kelbia, Tunis (D'Ancona 1954)

6.5.2 Transplantation Introduction

Specimens of *M. cephalus* have been transplanted to the Caspian Sea, but have not thrived as well as two other species of mullet transplanted with them (Babayan 1958).

7. POND FISH CULTURE

7.1 Culture areas

Table 37 shows details of areas where M. cephalus is farmed.

TABLE 37

AREAS WHERE M. CEPHALUS IS FARMED

Region	Country	Primary, secondary or experimental crop	Associated species
Arcachon	France	secondary	eels, other mullet, Labrax spp. Arné (1938)
	Israel	experimental	European carp, other mullet Pruginin and Kitai (1957)
Kyamkulam	India	experimental	Jones (1951)
Nar	India	primary (60%)	Chanos chanos (40%) Pillay (1948)
Madras	India	secondary	Lates calcarifer, Chanos chanos, Ganapati et al. (1950)
Po. R. delta	Italy	secondary	eels, other mullet, Sparus sp., Morone sp. Beadle (1946); D'Ancona (1954)
Hong Kong		primary	carps Chow (1958b)
	Japan	secondary	eels Nakamura (1949)
	Korea	experimental	Anonymous (1961)
Florida	U.S.A.	experimental	Johnston (1954)
Nth Luzon	Philippines	secondary	Chanos chanos Acosta (1953)
Lake Qarun	Egypt	primary	other mullet Faouzi (1936)

7.2 Procurement of stock

TABLE 38

METHODS OF PROCUREMENT OF MULLET FRY

Locality	Authority	Free entry	Seine hauling nets	Set nets	Dip nets	Coarse cloth
China	Hora and Pillay (1962)				x	
India						
Narakal	Pillay (1948)			x		
Contai	Pillay (1949)					x
Madras	Hora and Pillay (1962)		x			
Israel	Perlmutter *et al.* (1957)		x			
Italy	Angelis (1955)	x	x			
France						
Arcachon	Arné (1938)	x				
Hong Kong	Pillai (1962)		x		x	
Philippines						
Nth Luzon	Blanco and Acosta (1949)	x				
Japan	Nakamura (1949)		x			
Hawaii	Hora and Pillay (1962)	x				

TABLE 39

TIME OF COLLECTION OF MULLET FRY

Country	Time of collection	Authority
India	December to March	Hora and Pillay (1962)
Hong Kong	February to April	Hora and Pillay (1962)
France	February to April	Arné (1938)
Israel	September to December	Perlmutter and Pruginin (1957)
Philippines	April to July	Blanco and Acosta (1938)

TABLE 40

RATE OF STOCKING OF MULLET FRY

Area	Number per hectare	Authority
Hong Kong	15,000+	Pillai (1962)
Hong Kong	12,000 - 30,700x	Lin (1955)
Italy	300 - 400*	Angelis (1955)

\+ plus 1500 - 2500 carp x plus 6,000 - 15,000 carp * plus eels etc.

Mullet culture takes place in brackish water in most places, but fry are acclimatized to freshwater in parts of India (Madras region) (Ganapati et al. 1950) and in China (Hora and Pillay 1962).

7.3 Genetic selection of stocks None

7.4 Spawning (artificial)

None recorded, though a group in Israel are experimenting (Perlmutter and Pruginin (1957). (On laboratory scale - see Section 3.1.6).

Spawning (induced) None recorded

Spawning (natural) None in ponds (see Section 3.1.6)

7.5 Holding of stock

Held in ponds 2-4 ft deep, usually as two or three year crop, but sometimes for one year only.

In Italy, France, and Japan the main crop in many fish ponds is the eel, for which the mullet act as forage food. But the surplus mullet are also marketed.

In Hong Kong, to avoid overcrowding the mullet are regularly thinned out after they reach a size of five inches (Lin 1955). Pond types differ widely from partially enclosed lagoons, as many of the Italian 'valli' (D'Ancona 1954), to artificial ponds, as in Indonesia and Japan. In some there is complete tidal interchange through screens. Other ponds have one way valves which allow water to enter the ponds at high tide but shut to prevent it leaving on the ebb. In some of the more advanced 'valli' both fresh and salt water intake can be controlled (Angelis 1955).

7.6 Pond management

Mullet farms have not been extensively fertilized except in Japan and Hong Kong where organic fertilizers are largely used in ponds or on the adjoining lands which drain into the ponds. Some little has been done in Italy (D'Ancona 1954). Control of vegetation is necessary at times in the Italian 'valli' to prevent deoxygenation and the vegetation is raked into heaps to rot and refertilize the ponds.

7.7 Foods : feeding

Mullet feed on microscopic life and detrital organic matter, as well as on filamentous green and blue-green algae. There are no records of artificial feeding.

7.8 Disease and parasite control No records

7.9 Harvest

In Italy and France large mullet as they mature are harvested in traps placed near entrances, as they attempt to leave the ponds (D'Ancona 1954; Arné 1936). In most other places they are fished from the ponds either by seines or cast nets.

TABLE 41

YIELD OF MULLET PER HECTARE

Area	Number per hectare	Authority
Hong Kong	1470	Pillai (1962
Hong Kong	1872 - 2434	Lin (1955)
Italy	100 - 1400+	D'Ancona (personal communication)
India (Narakal)	1000	Pillay (1948)

7.10 Transport No information

8. REFERENCES

Acara, A. and F. Gozenalp, 1959 Contribution on the northern lagoons of the Sea of Marmora. Proc. gen. Fish. Coun. Medit., 5 : 235-40

Acosta, P.A., 1953 Inland fisheries of the Philippines. "Philippine Fisheries". 8th Pacif. Sci. Congress Handbook, : 124-31

Alexander, C.G., 1954 Microcotyle macracantha n. sp., a monogenetic trematode from the Gulf of California. J. Parasit., 40(3) : 279-83

Alexandrova, K., 1957 The growth of cefala (M. cephalus) on the Bulgarian Black Sea coast. Bulg. Sci. Res. Inst. Fish. Sci. Paper, 1 : 59-76 (In Bulgarian, summaries in English and Russian)

Anderson, W.W., 1958 Larval development, growth and spawning of striped mullet (Mugil cephalus) along the south Atlantic coast of the United States. Fish. Bull. U.S., 144 : 501-19

Angelis, R. de, 1955 The capture and acclimatization of sea fry with a view to stocking inland waters. Proc. gen. Fish. Coun. Medit., 3 : 243-51

Angelis, R. de, 1960 Mediterranean brackish water lagoons and their exploitation. Stud. Rev. gen. Fish. Coun. Medit., 12 : 1-41

Anonymous, 1933 Annual report of the research institute and the endemic diseases hospital. Minister of the Interior, Egypt

Anonymous, 1951 Florida mullet production low. Fish. Gaz., 68(1) : 110

Anonymous, 1958 Illustrations of Japanese fishing boats and fishing gear. Jap. Ass. Agric. For.

Anonymous, 1961 A preliminary brief report on artificial mullet (Mugil sp.) culture in Korea. Indian Fish. Bull., 8(2) : 21

Arné, P., 1938 Contribution a l'étude de la biologie des muges du Golfe de Gascoyne. Rapp. Comm. int. Mer Médit., 11 : 77-116

Arnold, E.L. and J.R. Thompson, 1958 Offshore spawning of the striped mullet Mugil cephalus in the Gulf of Mexico. Copeia, 1958(2) : 130-2

Asada, J., 1928 Studies on human trematodes of the genus Heterophyes occurring in Japan. I. Determination of the first intermediate host of H. heterophyes and experimental investigation of the life history. Tokyo Iji-Shsh., 2564 : 6-12 (In Japanese)

Babayan, K.E., 1958 Caspian mullet. Zool. Zh., 36 : 1505-13 (In Russian, English summary).

Beadle, L.C. 1946 The Venetian lagoon. Sci. Progr., 34 : 734-50

Belloc, G., 1938 Biologie et pêche de l'Etang de Biguglia. Rapp. Comm. int. Mer Médit., 11 : 433-73

Bere, R., 1936 Parasitic copepods from Gulf of Mexico fishes. Amer. Midl. Nat., 17(3) : 577-613

Berg, L.S. et al., 1949 Commercial fishes of the U.S.S.R. Food Industry Moscow (In Russian)

Blanco, G.J. and P.A. Acosta, 1958 The propagation of the grey mullet in northern Luzon brackish-water fish ponds. Philipp. J. Fish., 6(1) : 1-5

Bleeker, P., 1863 Memoire sur les poissons de la côte de Guinée. Natuurk. Verh. Holland Maatsch. Wet., 18(2) : 1-136

Bloch, M.E., 1788 Ichthyologie, ou histoire naturelle, generale, et particulière des poissons. 12. Berlin

Boeseman, M., 1947 Revision of the fishes collected by von Siebold in Japan. Zool. Meded., 28 : 1-242

Boulenger, G.A., 1916 Catalogue of the fresh-water fishes of Africa in the British Museum. 4 : 1-179

Breder, C.M., 1940 The spawning of Mugil cephalus on the Florida west coast. Copeia, 1940(2) : 138

Breuer, J.P., 1957 Ecological survey of Baffin and Alazan Bays, Texas. Publ. Inst. Mar. Sci., 4(2) : 134-55

Broadhead, G.C., 1953 Investigations of the black mullet, Mugil cephalus L., in northwest Florida. Florida Bd. Conserv. Tech. Ser., 7 : 1-33

Broadhead, G.C., 1958 Growth of the black mullet (Mugil cephalus L.) in west and northwest Florida. Florida Bd. Conserv. Tech. Ser., 25 : 1-29

Broadhead, G.C. and H.P. Mefford, 1954 Interim report on mullet research. Marine Lab. Univ. Miami Spec. Serv. Bull., 8 : 1-9

Broadhead, G.C. and H.P. Mefford, 1956 The migration and exploitation of the black mullet, Mugil cephalus L., in Florida, as determined from tagging during 1949-1953. Florida Bd. Conserv. Tech. Ser., 18 : 1-31

Bromhall, J.D., 1954 Note on the reproduction of the grey mullet, Mugil cephalus Linnaeus. Hong Kong Univ. Fish J., 1 : 19-34

Bykhovskaya-Pavlovskaya, I.E. and G.K. Petrushevski, 1957 The larvae of avian and mammalian trematodes in the fishes of the USSR. Sovesch. po. bolezn. ryb. (Abstracts) Publ. : AN S.S.S.R. (Quoted in Dogiel et al. 1958)

Cabo, F.L., 1959 Fishing gear used in Spanish coastal lagoons. Stud. Rev. gen. Fish. Coun. Medit., 9 : 1-7

Castelnau, F. de, 1861 Memoire sur les poissons de l'Afrique australe. Baillière, Paris. 78 p.

Castelnau, F. de, 1873 Contribution to the ichthyology of Australia. VIII. Fishes of Western Australia. Proc. Zool. Acclimat. Soc. Victoria, 2 : 123-49

Castelnau, F. de, 1875 Researches on the fishes of Australia. Intercol. Exhib. Essays Philadelphia, Victorian Office Records

Chabanaud, P., 1926 Sur divers poissons de mer de la côte occidentale d'Afrique; description de deux espèces nouvelles. Bull. Soc. Zool. Fr., 51 : 8-16

Chacko, P.I., 1949a On the nutrition of young stages of certain estuarine fishes of Madras. Proc. 36th Ind. Sci. Congress, 3 : 163-4

Chacko, P.I., 1949b Food and feeding habits of the fishes of the Gulf of Manaar. Proc. Indian Acad. Sci., 29 : 83-97

Chow, T., 1958a Growth characteristics of four species of food fish in Hong Kong. Hong Kong Univ. Fish. J., 2 : 29-36

Chow, T., 1958b The bionomics of pondfish culture in the new territories, Hong Kong. Hong Kong Univ. Fish. J., 2 : 131-2

Ciurea, I., 1931 Les poissons de la mer noire comme source d'infestation par les trematodes de famille des Heterophyides et des Echinostomides. Arch. Roumaine Path. Exp. Microbiol., 4 : 289-99

Cole, B.T., H.J. Bennett and J.D. Miller, 1958 Tolerance of euryhaline forms to dilution of oil-feed bleed water. Proc. Louisiana Acad. Sci., 20 : 13-23

Craig-Bennett, L., 1938 The grey mullet fishery of Palestine. Rapp. Comm. int. Mer Medit., 11 : 69-72

Cuvier, G.L., La Regne Animal 2. Paris
1892

D'Ancona, U., Fishing and fish culture in brackish water lagoons. FAO Fish.
1954 Bull., 7(4) : 147-72

Dannevig, J.C., On some peculiarities in our coastal winds and their influence
1907 upon the abundance of fish in inshore waters. J. Proc. roy. Soc.
N.S.W., 41 : 27-45

Darnell, R.M., Food habits of fishes and larger invertebrates of Lake
1958 Pontchartrain, Lousiana, an estuarine community. Publ. Inst. Mar.
Sci., 5 : 353-416

Darnell, R.M., Trophic spectrum of an estuarine community based on studies of
1961 Lake Pontchartrain, Lousiana. Ecology, 42(3) : 353-416

Day, F., The fauna of British India. Fishes. 2.
1889 Tayler and Francis. London

Dekhnik, T.V., Reproduction of Mugil cephalus in the Black Sea.
1953 C.R. Acad. Sci. URSS, 93 : 201-4 (In Russian)

Delury, D.B., On the planning of experiments for the estimation of fish
1951 populations. J. Fish. Res. Bd. Canada, 8 : 281-307

Denizci, R., Some thoughts about the biology of common grey mullet (M. cephalus)
1958 in the waters of Istanbul and its surroundings. Rapp. Comm. int.
Mer Médit., 14 : 359-68

Devasundaram, M.P., Scale study of Mugil cephalus Linnaeus of Chilka Lake,
1952 J. Madras Univ., B22(1) : 147-63

DeVis, C.W., New fishes in the Queensland museum. Proc. Linn. Soc. N.S.W.,
1884 9(2) : 869-87

Dogiel, V.A., H.K. Petrushevski and Y.I. Polyanski, Parasitology of fishes
1958 Leningrad University Press. (In Russian)
(Also in English translation, 1960 Oliver and Boyd. Edinburgh and
London).

Earll, R.E., The mullet fishery: In the fisheries and fishery industries of
1887 the United States. (ed. G.B. Goode). Washington

Ebeling, A.W., Mugil galapagensis, a new mullet from the Galapagos Islands.
1961 Copeia, 1961(3) : 295-304

Ellis, R., Mullet research in Florida. Progr. Fish. Cult., 21(1) : 34-5
1959

Erman, F., 1959 Observations on the biology of the common grey mullet (Mugil cephalus). Proc. gen. Fish. Coun. Medit., 5 : 157-69

Faouzi, H., 1938 Quelques aspects de la biologie des muges en Egypte. Rapp. Comm. int. Mer Médit., 11 : 63-8

Follett, W.I., 1960 The biogeography of Baja California and adjacent seas: the freshwater fishes, their origins and affinities. Systematic Zoology, 9 : 212-32

Forskål, P., 1775 Descriptione animalium, avium, amphiborum, piscium, insectorum, vermium, quae in itinere orientale observant.

Fowler, H.W., 1936 The marine fishes of West Africa. Bull. Amer. Mus. nat. Hist., 70(1) : 1-605

Ganapati, S.V. et al., 1950 On the acclimatization, transport, and culture of some salt water fishes in inland waters of the Madras State. Indian Geogr. J., 25(2) : 1-15

Gay, C., 1847 Historia fisica y politica de Chile. 2. Paris

Ghazzawi, F.M., 1933 The pharynx and intestinal tract of the Egyptian mullets Mugil cephalus and Mugil capito pt. 1. On the food of the mullet from Egyptian waters. Fish. Res. Direct. Egypt Notes and Mem., 5 : 1-18

Gideon, R. (Ed.), 1953 Laws of the State of Israel., 11 : 807-17 Tel Aviv

Gilchrist, J.D. and W.W. Thompson, 1914 Descriptions of fishes from the coast of Natal. Ann. S. Afr. Mus., 13 : 65-95

Girard, C.F., 1859 Ichthyology in United States and Mexican boundary survey 2(2) : 1-85

Gnanamathu, C.P., 1943 The foraminifera of Krusadai Island. Bull. Madras Govt. Mus., 1(2), 5 : 1-21

Gunter, G., 1945 Studies on marine fishes of Texas. Publ. Inst. Mar. Sci. Univ. Tex., 1(1) : 1-190

Gunther, A., 1861 Catalogue of the acanthopterygian fishes in the collection of the British Museum. 3 : 1-586

Gunther, A., 1876 Remarks on fishes with descriptions of new species in the British Museum, chiefly from southern seas. Ann. Mag. nat. Hist., (4)17 : 384-402

Gunther, A., 1880a A contribution to the knowledge of the fish fauna of the Rio de la Plata. Ann. Mag. nat. Hist., (5)7 : 7-13

Gunther, A., 1880b Report on the shore fishes. Zool. Challenger Exp., 1(16) : 1-82

Gunther, A., 1880c An introduction to the study of fishes. Edinburgh

Hargis, W.J., 1956 Monogenetic trematodes of the Gulf of Mexico fishes. X. The family Microcotylidae Toschenberg 1879. Trans. Amer. micr. Soc., 75(4) : 436-53

Hendricks, L.J., 1961 The striped mullet Mugil cephalus Linn. Calif. Fish & Game Fish. Bull., 113 : 95-104

Hiatt, R.W., 1944 Food chains and food cycle in Hawaiian fish-ponds. I. The food and feeding habits of mullets (Mugil cephalus), milk fish (Chanos chanos) and the tenpounder (Elops machinata). Trans. Amer. Fish. Soc., 74 : 250-261

Higgins, E., 1928 Progress in biological enquiries, 1926. Rep. U.S. Comm. Fish., 1928 (Doc. 1029) : 517-681

Higgins, E., 1932 Progress in biological enquiries, 1931. Rep. U.S. Comm. Fish., 1932 : 441-529

Hildebrand, S.F., 1946 A descriptive catalogue of the shore fishes of Peru. Bull. U.S. nat. Mus., 189 : 1-530

Hiscock, I.D., 1954 A new species of Otobothrium (Cestoda, Trypanorhyncha) from Australian fishes. Parasitology, 44 : 65-70

Hora, S.L. and T.V.R. Pillay, 1962 Handbook on fish culture in the Indo-Pacific Region. FAO Fish. Biol. tech. Pap., 14 : 1-204

Horstmann, E., 1959 Schwarmstudien unter Ausnutzung einer optomotorische Reaktion bei Mugil cephalus (Cuv.) Publ. Staz. Zool. Napoli, 31(1) : 25-35

Hotta, H., 1955 On the mature mugilid fish from Kabashima, Nagasaki prefecture Japan, with additional notes on the intestinal convolution of Mugilidae. Jap. J. Ichthyol., 4 : 162-9 (In Japanese; English summary)

Howard, K.T., N.B. Marshall and R.S. Wimpenny, 1955 A voyage to the black hake grounds off the west African coast. Rapp. Cons. Explor. Mer, 137 : 53-6

Hoxie, W., 1884 Occurrence of mullet in freshwater. Bull. U.S. Fish. Comm. 4 : 80

Hubbs, C.L., 1921 Remarks on the life history and scale characters of American mullets. Trans. Amer. micr. Soc., 40 : 26-7

Hutton, R.F. and F. Soganderes-Bernal, 1959a Studies on the trematode parasites encysted in Florida mullets. Florida Bd. Conserv. Spec. Sci. Rep., 1 : 1-88

Hutton, R.F. and F. Soganderes-Bernal, 1959b Further notes on Trematoda encysted in Florida mullet. Quart. J. Florida Acad. Sci., 21(4) : 329-34

Idyll, C.F., 1950 The Florida mullet research programme. Proc. Gulf Caribb. Fish. Inst., 2 : 44-5

Jacob, P.K. and B. Krishnamurthi, 1948 Breeding and feeding habits of mullet (Mugil) in Ennore creek. J. Bombay nat. Hist. Soc., 47 : 455-7

Jacot, A.P., 1920 Age, growth and scale characters of the mullets Mugil cephalus and Mugil curema. Trans. Amer. micr. Soc., 39 : 199-229

Job, T.J. and P.I. Chacko, 1947 Rearing of salt water fishes in freshwaters of Madras. Indian Ecol., 2(1) : 1-9

John, C.M., 1955 The grey mullets of Kyamkulam Lake, India and their fishery. Copeia, 1955(3) : 225-30

Johnson, M.C., 1954 Preliminary experiment in fish culture in brackish-water ponds. Progr. Fish. Cult., 16(3) : 131-3

Johnston, T.H., 1917 Notes on a Saprolegnia epidemic amongst Queensland fish Proc. roy. Soc. Qld., 29 : 125-33

Jones, S., 1951 Principal estuarine fisheries. Fisheries of the embanked brackish-waters.

Jordan, D.S. and J.O. Snyder, 1901 List of the fishes collected in 1883 and 1885 by Pierre Louis Jouy and preserved in the United States Museum. Proc. U.S. nat. Mus., 23 : 739-69

Jordan, D.S. and J. Swain, 1885 A review of the American species of marine Mugilidae. Proc. U.S. nat. Mus., 7 : 261-75

Kawakami, M., 1917 Oecological studies on mullets report 1. Marine Products Res. Lab. J., 12(4) (Quoted in Hotta 1955).

Kesteven, G.L., Studies on the biology of Australian mullet. 1. Account
1942 of the fishery and preliminary statement of the biology of *Mugil dobula* Gunther. *Coun. sci. industr. Res. Aust. Bull.*, 157 : 1-147

Kesteven, G.L., Further results of tagging sea mullet, *Mugil cephalus* Linnaeus.
1953 on the eastern Australian coast. *Aust. J. Mar. Freshw. Res.*, 4 : 251-306

Klunzinger, C.B., Synopsis der Fische des Rothen Meeres I. Percoiden-Mugiloiden.
1870 *Verh. zool.-bot. Ges. Wien.*, 20 : 669-834
(Also published separately with Part II in 1871)

Klunzinger, C.B., Zur Fischfauna von Sud-Australien. *Arch. Naturgesch.*,
1872 38 : 19-47

Klunzinger, C.B., Die von Müller'sche Sammlung australischer Fische im
1880 Stuttgart. *Sitzber. Akad. Wiss. Wien.*, 80(10) : 325-430

Kunstler, M.J., Note sur les moeurs du muge de l'étang de Limizan.
1904 *C.R. Soc. Biol. Paris*, 56 : 427-8

Kuthalingam, M.D.K., Temperature tolerance of the larvae of ten species
1959 of marine fishes. *Curr. Sci.*, 28 : 75-6

Lake, J.S. The freshwater fishes of New South Wales. *N.S.W. State Fish. Res.*
1959 *Bull.*, 5 : 1-19

Lin, S.Y., Chinese systems of pond stocking. *Indo-Pac. Fish. Coun. Proc.*,
1955 1954(2) : 113-25

Linnaeus, K. von, Systema Naturae ed. 10.
1758

Linnaeus, K. von, Systema Naturae ed. 12.
1766

McCulloch, A.R., Check-list of the fishes and fish-like animals of New South
1921 Wales. part 2. *Aust. Zool.*, 2(2) : 24-68

McCulloch, A.R., A check-list of the fishes recorded from Australia.
1929 *Mem. Aust. Mus.*, 5 : 1-534

Machado, D.A., Uma nova especie do genero "Atactorhynchus" Van Cleave
1951 (Chandler) 1935 (Acanthocephala : Neoechinrhynchidae). *Rev. Brasil Biol.*, 11(1) : 29-31

MacInnes, I.G. (Ed.), Australian Fisheries. A handbook prepared for the second
1950 meeting of the Indo-Pacific Fisheries Council. Halstead Press. Sydney

MacIntyre, R.J., 1959 Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. VII. The benthic macro-fauna. Aust. J. Mar. Freshw. Res., 10 : 341-53

McNally, J., 1957 The feeding habits of cormorants in Victoria. Victoria Fauna Contrib., 6 : 1-36

Martin, W.E., 1958 The life histories of some Hawaiian heterophyid trematodes J. Parasit., 44(3) : 305-23

Miller, R.R., 1958 Origin and affinities of the freshwater fish fauna of western North America. Amer. Ass. Adv. Sci. Publ., 51 : 187-222

Mohr, E., 1927 Mugiliden Studien. Zool. Jahrb., 54 : 177-201

Montes, H.W., 1931 Some digenetic trematodes of marine fishes of Beaufort. North Carolina. Parasitology, 23(3) : 396-411

Moody, W.P., 1950 A study of the natural history of the spotted trout, Cynoscion nebulosus, in the Cedar Key, Florida, area. Quart. J. Fla. Acad. Sci., 12(3) : 147-71

Morovic, D., 1954 Contribution a la connaissance de la croissance annuelle de Mugil cephalus (L) dans quelques "valli da pesca" du littoral venitien. Rapp. Comm. int. Mer Médit., 12 : 203-17

Nair, G.S., 1957 Notes on the early development of Mugil cephalus Linnaeus Bull. Centr. Res. Inst. Univ. Travancore, C 5(1) : 77-84

Nakamura, N., 1949 Some notes on the pond-culture of mullets. Bull. Jap. Soc. Sci. Fish., 14(4) : 211-15 (In Japanese : English summary)

Nakano, M., 1918 Oecological studies on mullets. Report 2. Marine Products Res. Lab. J. 13(4) : (Quoted in Hotta 1955)

Ogilby, J.D., 1897 On new genera and species of Australian fish. Proc. Linn. Soc. N.S.W., 22 : 62-95

Ommaney, F.D., 1949 Age investigations in Mauritius fishes. Roy. Soc. Arts. Sci. Mauritius Trans., C 15 : 38-59

Orcutt, C.R., 1891 A visit to Lake Maquata. West. Amer. Sci., 7 : 158-64

Ozaki, H., 1951 On the relation between the phototaxis and the aggregation of young marine fish. Rep. Fac. Fish. Univ. Mie, 1(1) : 55-6

Palombi, A., 1931 Per una migliare conscienza dei trematoda endoparassiti dei pesci del Golfo di Napoli. I. Steringotrema divergens (Reid); Haploporus benedeni (Stoss). Ann. Mus. Zool. R. Univ. Napoli, 6(6) : 1-5

Parona, C. and A. Perugia, 1890 Res ligusticae XIV. Ann. Mus. Civ. Stor. nat di Genova (2) 9 : 171-220

Perlmutter, A., L. Bograd and J. Pruginin, 1957 Use of the estuarine and sea fish of the family Mugilidae (grey mullets) for pond culture in Israel. Proc. gen. Fish. Coun. Medit., 4 : 289-304

Petrushevski, G.K. and S. Shulman, 1958 The parasitic diseases of fishes in the natural waters of the USSR. In Dogiel et al. 1958 : 299-319

Phillips, R.C. and V.G. Springer, 1960 A report on the hydrography, marine plants and fishes of the Caloosahatchie River area, Lee county Florida. Florida Bd. Conserv. Spec. Sci. Rep., 5 : 1-34

Pillai, T.G., 1962 Fish farming methods in the Philippines, Indonesia and Hong Kong. FAO Fish. Biol. tech. Paper, 18 : 1-68

Pillay, T.V.R., 1948 A mullet farm in Cochin State. Indian Farming, 9 : 99-103

Podder, T.N., 1937 On a new species of Neoechinorhynchus parasitic on M. cephalus from Chilka Lake. Rec. Indian Mus., 39(11) : 129-31

Popov, A.M., 1930 Teratological material from the ichthyofauna of the Black Sea. Bull. Acad. Sci. URSS Cl. Sci. Phys-Math., 1930(10) : 1053-78

Prabhu, M.S., 1950 On the breeding habits of the ribbonfish Trichiurus haumela Forskal. Curr. Sci., 19(7) : 213-4

Pruginin, Y. and H. Kitai, 1957 Cultivating mullets as a secondary fish in the carp ponds. Bull. Fish. Cult. in Israel (Bamidgeh), 9(4) : 70-5

Radovich, G., 1961 Relationship of some marine organisms of the north east Pacific to water temperatures. Calif. Fish. Bull. 112 : 1-62

Rasalan, S.B., 1953 Fishing gear commonly used in Philippine fishing. In "Philippine Fisheries". 8th Pacific Sci. Congress Handbook

Riggs, C.D., 1957 Mugil cephalus in Oklahoma and northern Texas. Copeia, 1957(2) : 158-9

Robinson, D.T., 1959 The ichthyofauna of the lower Rio Grande, Texas and Mexico. Copeia, 1959(3) : 253-6

Rosa, H., 1962 Preparation of synopses on the biology of species of living aquatic organisms. FAO Fish. Biol. Synopsis, 1 : 1-52

Roughley, T.C., 1916 Fishes of Australia and their technology. Sydney

Roule, L., 1915 Sur les migrations des poissons du genre Mugil dans l'Etang de Thau. C.R. Soc. Biol. Paris, 161 : 537-9

Saidov, Y.S., 1953 Helminth fauna of fishes and piscivorous birds of Dagestan Rept. Vses. in-t gelm. im Skryabina (quoted in Dogiel et al. 1958)

Sanzo, L., 1930 Uova e larve di Mugil cephalus Cuv. ottenute per efecondazione artificielle (Note preventiva). R. Com. Talass. Ital. Mem., 179 : 3

Sanzo, L., 1936 Contributi ulla conoscenza dello sviluppo embrionale e post-embrionale nei Mugilidi. R. Com. Talass. Ital. Mem., 230 : 1-11

Saville-Kent, W., 1889 Food fishes of Queensland. Qld. Parliament. Paper CA52-1889

Schlegel, H., 1845 Pisces: in von Siebold "Fauna Japonica" Leyden.

Schultz, L.P., 1946 A revision of the genera of mullets, fishes of the family Mugilidae, with descriptions of three new genera. Proc. U.S. nat. Mus., 96 : 377-95

Schultz, L.P., 1949 A further contribution to the ichthyology of Venezuela. Proc. U.S. nat. Mus., 99 : 1-211

Serbetis, C.D., 1939 L'eta e l'accrescimento dei Mugilidi. Boll. Pesca Piscicolt. Idrobiol Roma, 15 : 628-707

Serventy, D.L., 1938 The feeding habits of cormorants in south-western Australia Emu., 38 : 293-316

Serventy, D.L., 1939 Notes on some fish-eating birds other than cormorants. Emu, 38 : 510-12

Shino, S.M., 1955 Copepods parasitic on Japanese fishes. Rep. Fac. Fish. Univ. Mie, 2(1) : 50-69

Siebenaler, J.B., 1955 Commercial fishing gear and fishing methods in Florida. Florida Bd. Conserv. Tech. Ser., 12 : 1-45

Slastenenko, E.P., 1956 The fishes of the Black Sea Basin. Istanbul. 711 p. (In Turkish)

Simmons, E.G., 1957 Ecological survey of the upper Laguna Madre of Texas. Publ. Inst. Mar. Sci. Univ. Tex., 4(2) : 156-200

mith, H.M., The fishes found in the vicinity of Woods Hole. Bull. U.S. Fish
1898 Comm., 17 : 85-111

mith, J.L.B., The fishes of the family Mugilidae in South Africa.
1935 Ann. S. Afr. Mus., 30 : 587-644

pringer, V.G. and K.D. Woodburn, An ecological study of the fishes of the
1960 Tampa Bay area. Florida Bd. Conserv. Prof. Paper, 1 : 1-104

purgeon, V.D., Natural acclimatization of two species of mullets Mugil
1947 dussumieri (C.V.) and Mugil oeur (Forsk) to freshwater conditions on the Nellore coast. Curr. Sci., 16 : 123-4

teindachner, F., Ichthyologische Beitrage. 3.
1876 Sitzber. Akad. Wiss. Wien., 72 : 29-96

tenger, A.H., A study of the structure and development of certain reproductive
1959 tissues of Mugil cephalus. Zoologica, 44(2) : 53-70

tephenson, W. and E.M. Grant, Occurrence of sea mullet (Mugil cephalus L.)
1954 on Heron Island, Capricorn Group. Aust. J. Sci., 17(3) : 102-103

umner, F.B., R.C. Osborn and L.J. Cole, A biological survey of the waters of
1911 Woods Hole and vicinity. Bull. U.S. Bur. Fish., 31(2) : 545-860

utton, J.W., Gear studies in the Florida mullet fishery. Proc. Gulf and
1950 Caribb. Fish. Inst., 2 : 47-50

ylva, D.P., H.B. Stearns and D.C. Tabb, Populations of the black mullet
1956 (Mugil cephalus) in Florida. Florida Bd. Conserv. Tech. Ser., 19 : 1-45

aylor, H.F., Survey of the marine fisheries of North Carolina. Chapel Hill,
1951 New York, 545 p.

enison-Woods, J.E., Fish and Fisheries of New South Wales.
1882 Government Printer, Sydney.

hatcher, V.E. and A.K. Sparks, A new species of Dicrogaster (Trematoda
1958 Hoplosporidae) from Mugil cephalus in the Gulf of Mexico. J. Parasit., 61(6) : 647-88

homson, J.M., The effect of a period of increased legal minimum length on
1950 sea mullet in Western Australia. Aust. J. Mar. Freshw. Res., 1 : 199-220

homson, J.M., Growth and habits of the sea mullet, Mugil dobula, Gunther, in
1951 Western Australia. Aust. J. Mar. Freshw. Res., 2 : 193-225

Thomson, J.M., 1953 Status of the fishery of sea mullet (Mugil cephalus Linnaeus) in eastern Australia. Aust. J. Mar. Freshw. Res., 4 : 41-81

Thomson, J.M., 1954a The Mugilidae of Australia and adjacent seas. Aust. J. Mar. Freshw. Res., 5 : 70-131

Thomson, J.M., 1954b The organs of feeding and the food of some Australian mullet. Aust. J. Mar. Freshw. Res., 5 : 469-85

Thomson, J.M., 1955 The movements and migrations of mullet (Mugil cephalus L.) Aust. J. Mar. Freshw. Res., 6 : 328-47

Thomson, J.M., 1957a The penetration of estuarine fish into freshwater in the Albert River. Proc. roy. Soc. Qld., 68(3) : 17-20

Thomson, J.M., 1957b The food of Western Australian estuarine fish. W.A. Fish. Dep. Fish. Bull., 7 : 1-13

Thomson, J.M., 1957c The size at maturity and spawning times of some Western Australian estuarine fishes. W.A. Fish. Dep. Fish. Bull., 8 : 1-8

Thomson, J.M., 1959 Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. VIII-XII. Aust. J. Mar. Freshw. Res., 10 : 354-408

Tressler, D.K., 1951 Marine Products of Commerce. Reinhold, New York. p. 266

Tschudi, F. von, 1845 Untersuchungen uber die Fauna Peruana, St. Gallen. Ichthyologie, 1 : 1-35

Valenciennes, A., 1836 Histoire naturelle de poissons. 2 : 1-506. Paris

Vlasenko, P.V., 1932 On the parasitic helminths of the Black Sea fishes. Trav. Sta. Biol. Karadagh, 4 : 88-136

Vodyanitskii, V.A. and I.I. Kazanova, 1954 The identification of pelagic eggs and larvae of Black Sea fishes. Trudy Vsesoiuonovo N-I Inst. (Mosk) Ryb. Khoz. Okeanogr., 28 : 240-323 (In Russian)

Vogt, C., 1878 Uber die Entwicklungsorgane einiger ectoparasitischer mariner Trematoda. Z. wiss. Zool., 30 (Suppl.) : 327

Whitley, G.P., 1948 A list of the fishes of Western Australia. W.A. Fish. Dep. Fish. Bull., 2 : 1-35

/ood, E.J.F., 1959 Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. VI. Plant communities and their significance. Aust. J. Mar. Freshw. Res., 10 : 322-40

/impenny, R.S., 1932 Observations on the size and growth of two Egyptian mullets, Mugil cephalus (Linn.), the "Bouri" and M. capito the "Tabar". Min. Finance, Coastguards and Fisheries Services, Cairo

'amaguti, S., 1938 Studies on the helminth fauna of Japan. Trematodes of fish. V. Japanese J. Zool., 8(1) : 15-74

'arrell, W., 1836 A history of British fishes. London

'ang, W.T. and U.B. Kim, 1962 A preliminary report on the artificial culture of grey mullet in Korea. Proc. Indo-Pac. Fish. Coun., 9(2-3) : 62-70

'okota, T. et al., 1961 Studies on the feeding habit of fishes. Rep. Nankai Reg. Fish. Res. Lab., 14 : 1-234