CSIRO Marine Laboratories Report

Determination of Biological Parameters required for the Rational Management and Exploitation of the Fishes of the Gulf of Carpentaria

Final Report
FRDC Project 91/29

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Summary

This project examined aspects of the biology of commercially important demersal fishes of the Gulf of Carpentaria (GOC). Such data were urgently required to allow accurate estimates of MSY and TAC for the new management zone of the central and northern GOC. The study provides new information on the growth rates, mortality rates, reproduction and spawning grounds of the important snapper and emperor species of the GOC. Particular attention was paid to the red snappers, Lutjanus malabaricus and L. erythropterus. In addition, the project investigated relationships between bottom structure, made up of animals such as sponges, and fish distribution.

Discrepencies in the results from different methods of ageing the fishes led to the development of radiometric ageing techniques. This is only the second time such techniques have been employed and the first time for tropical fishes. The radiometric technique, using isotopes of lead, showed that ages taken from whole otoliths were accurate, but not those from sectioned otoliths or vertebrae. All the species studied lived less than 15 years and grew at similar rates up to an age of three.

Natural mortality estimates for the large lutjanids were consistent with the values already used in the annual northern demersal fish stock assessment workshops to estimate the optimal yield from this fishery. The assessment can now be expanded to include the other species examined that form a significant part of the catch and more accurately predict the total yield.

The reproductive data shows that each species has a protracted spawning season during the warmer months. Most species spawned throughout the GOC where they occurred, although spent L. malabaricus were only found in the north-western part of the GOC. If a large fishery were to develop the targeted spawning aggregations of this species, the impact of fishing on the stocks would increase significantly.

As most of the large species were sexually mature at 30cm, trawl codend mesh sizes over 10cm should ensure that most immature fishes escape the net. Reductions in trawl codend mesh size may impact on stocks by causing recruitment overfishing. It is recommended that mesh sizes remain at current sizes.

The data are available to describe the bottom structure of the GOC and the results are expected in the near future. Infauna distributions are related to sediment grain-size. This feature of the seabed of the GOC has a pattern of increasingly smaller grain-size across the GOC in a southeast-northwest direction. Muddier sediments were found in the northwestern GOC. The epibenthos is expected to show a trend that has a similar pattern. Once the community structure of the epibenthos is established the relationship

to the pattern in fish distribution can be explored. Key benthic prey can then be related to their contribution to the diets of the commercial species.

SECTION 3: BACKGROUND

Trawl fisheries are well established on the NW Shelf and in the Timor and western Arafura Seas. A demersal trawl fishery has recently developed in the northern GOC and is likely to extend to most of the deeper waters of the GOC in the near future. Whereas TAC's and management plans have been instituted for the established fisheries (See BRR Information Paper IP/6/90), insufficient was known of the GOC fish stocks for even interim management measures.

The lack of knowledge of species compositions and catch rates in the various regions of the GOC, particularly in relation to factors such as depth and benthos (ie. bottom structure), have been/are being addressed by the CSIRO/Raptis & Co. collaborative cruise of 1990 (supported also by AFS) and by the FIRDC Project 88/77 "Southern Surveyor" cruise of November-December 1990. These two research cruises are providing a vast amount of basic data which will be analysed and available during 1991/92. However, in order to provide adequate biological data and support for management, information on growth, mortality, spawning and specific relationships with benthos (i.e. structure and prey items) are required. The samples necessary for providing these data have/are being collected, but cannot be analysed with the presently available resources (manpower and $). The funding requested in this proposal will allow CSIRO to provide, in one year, important data for calculating more meaningful TAC's and making more rational management decisions.

The increasing pressure from industry for the opening of the central GOC to commercial fin-fish trawling makes it imperative that the data from the two cruises and the present proposal are made available as soon as possible. Some biological data (e.g. growth, mortality, spawning seasons) are available from NW Shelf (CSIRO) and Arafura (NT) work for certain species. However, these are likely to vary and the GOC represents an essentially unfished stock in an area where the bottom structure is minimally disturbed. In view of these points, and the differences between the GOC and the NW Shelf/Timor/Arafura Seas with regard to both physical (e.g. GOC not deeper than about 80 m) and biological factors (e.g. GOC has relatively high productivity) independent data must be obtained for the GOC. The sentiments expressed by Jernakoff and Sainsbury (BRR IP/6/90) that early scientific advice is vital for the future development of fisheries in the Arafura and Timor Seas is equally, if not more, applicable to the rapidly developing situation in the GOC.

These matters have been discussed extensively with AFS and the Research Committee of the Northern Fisheries Committee.

SECTION 4 - OBJECTIVES

To describe those aspects of the biology of the major commercial (or potentially commercial) trawl fish species in the Gulf of Carpentaria that are relevant to establishing a sustainable fishery, calculating TAC's and implementing a suitable management plan.

Species to be studied:

Lutjanus malabaricus Scarlet Perch
Lutjanus erythropterus Red Snapper
Lutjanus sebae Red Emperor
Lutjanus russelli Moses Perch
Lethrinus lentjan Red-spot Emperor
Lethrinus laticaudis Lesser Spangled Emperor
Diagramma pictum Painted Sweetlip

Biological parameters to be studied from presently unexploited populations:

- GROWTH -age determination from otoliths using standard techniques. Many of the otoliths have already been collected. Construction of length at age curves for each species by locality.
  - Use of length-frequency data to confirm and extend the otolithic ageing. Analyses by means of modal progression and the use of software such as MIX.
  - Comparisons of age/size structure with site, depth and bottom structure. Preliminary indications suggest that at least Lutjanus malabaricus and L. erythropterus are site segregated by size with the large and small fish around reefs but the commercial sized medium fish over less structured bottom - this concept needs to be rigorously tested.

- MORTALITY-initially will be calculated from the growth and length- frequency data - as the fishery develops it may be possible to use catch data. Some data are available for the current fishery operating along the northern borders of the NPF in the GOC.

- REPRODUCTION & SPAWNING AREAS -
  a) Use of Gonosomatic indices - much of the gonad material has already been collected.

b) Confirmation of macroscopic stageing, GSI and sex by histological sectioning of subsamples.
c) Comparisons of reproductive condition with site, season, depth, bottom structure and water temperature using data collected concurrently with the fish.

•RELATIONSHIPS WITH BENTHIC STRUCTURE & BENTHOS

- the benthic samples were collected opportunistically during field work associated with the FIRTA-funded project 88/77 "The fish resources of tropical northeastern Australian waters". Support is required for the sorting, identification and analysis of these epi-benthic dredge samples. The outputs will include:
- a description of the benthic community structure including species density, spatial patterns of distribution of numerically dominant species and a classification of the major benthic habitats, and their relationship to depth, sediment type, salinity, temperature and turbidity.
- the degree of coupling between the fish and benthos will be quantified by:-

(a) correlating the pattern of distribution of the fish site-groupings and the benthos site-groupings based on the numerical fish and benthos data (cophenetic correlation coefficient);
(b) identifying key benthic prey items and the degree of feeding selectivity of the fish by comparing the fish gut contents with the available benthos.

SECTION 5 - RESEARCH PROBLEM

Accurate estimates of age and growth are critical for the effective management of any fishery. Fisheries stock assessment models rely on an understanding of the age structure of the stocks and accurate estimates of growth rates to predict optimal exploitation rates and yields.

There have been few studies of age and growth of tropical Australian Lutjanids and Lethrinids, except for L. malabaricus. Studies on this species (Lai and Liu 1979; Chen et al 1984) used vertebrae and sectioned otoliths respectively to estimate ages. Both studies used the changes in the width of the marginal increment to verify that growth rings were formed once each year. At least three other species of Lutjanus form significant proportions of the catch. There are no published growth studies of these species from Australian waters.

Most fisheries models also require an estimate of natural mortality (M). In the Gulf of Carpentaria (GOC), stocks of demersal reef fish have not been fished by foreign trawlers since 1979. Recent demersal fish trawling by A.A. Raptis and Co also would have little impact on the stocks. Thus the stocks of reef fish in the GOC are virtually unexploited. This will provide an excellent opportunity to estimate the natural mortality directly rather than "guesstimating" the proportion of total mortality (Z) that may be attributed to natural mortality.

There were few data available on the reproduction of tropical Australian lutjanids and lethrinids especially the species in this study. Information on size and age at sexual maturity, spawning seasons and spawning frequency are important for managing the fishery when fishing pressure starts to impact on the stocks.

Studies on the the north-west shelf by CSIRO have focused on the relationship between benthic structure and fish distribution. They found that destruction of benthos by demersal trawling adversely affected the stocks of commercial fishes. No data were available to determine whether the distribution of major commercial species in the GOC are closely related to that of structured benthos. Catches of the fishes will decline rapidly if there is a close correlation and benthos is removed.

SECTION 6 - RESEARCH METHODS

Surveys

The FV 'Clipper Bird' shot five randomly positioned trawl tows in each of eight areas (Fig. 1a) in June 1990. A high-lift Pelegro fish trawl with a 46 m headrope and 102 mm cod-end mesh was rigged to Bison Boards (No 9) with 73 m sweeps and 46 m bridles. The trawl was towed at a speed of 3.3 knots (5.7 km h^{-1}) for 60 minutes. Almost all trawls were made during the day but at some sites it was necessary to trawl at night.

In November 1990, the RV 'Southern Surveyor' systematically transected the Gulf of Carpentaria and over 4 weeks sampled 105 stations in the stock assessment part of the survey (Fig. 1a). At each station, a Frank and Bryce demersal fish trawl was towed at a speed of 3.3 knots (max 5.5 knots, min 2.3 knots) for 30 minutes, day or night, but not 0.5 h either side of dawn and dusk or at depths less than 17 m. The Frank and Bryce trawl had a 26 m headrope and 50 mm cod end and was rigged with 50 m bridles to otterboards. Also at each station, a 4 m Church dredge was towed for 15 min for epibenthos, replicate sediment and infaunal samples taken with a 'Smith McIntyre' grab, and temperature, salinity, turbidity against depth profiles made with a 'Yeokal' data logger (Blaber et al. 1992).

During two weeks in November 1991, the RV 'Southern Surveyor' randomly sampled 65 stations in the Northern Gulf of Carpentaria. The Frank and Bryce trawl was rigged and used as in the previous November survey except that a 'Photosea' camera was mounted on the headrope. This camera took flash photographs of the substrate in front of the groundrope every minute. Shallower areas (>8m) were also sampled.

The catch composition in all surveys was determined by sorting the whole or a sub-sample of the catch to species level. The weight and numbers of each species were recorded and the standard lengths of all commercial fishes measured. During the November 1990 cruise, all fish were weighed (± 1 g), sexed and both otoliths (sagittae) removed dried and stored for later analysis. Subsequently, in November 1991, otoliths were kept only from fish in size classes that were underrepresented in previous samples. Vertebrae and scales were also taken from these fish and frozen for later examination of banding patterns.

Age and growth

In the laboratory, otoliths were cleaned of excessive tissue, dried at 60°C for 24 h, weighed (± 0.0001), measured along the longitudinal axis with dial callipers (± 0.05 mm) and assigned a sequential number. One otolith of each pair were embedded in polyester resin and sectioned with a diamond saw. The sections of each otolith were bonded to microscope slides with thermo-plastic cement. Each section was polished with 800 grit wet-and-dry sandpaper before being examined with a video-enhanced light microscope attached to a computer with distance measuring software. Presumed annuli were counted and the distance between annuli measured along an axis adjacent to the sulcus as bands were most distinguishable in this part of the otolith. Bands were also counted in whole otoliths when viewed against a strong point light source.

Details of methods used in radioanalysis of otoliths are given in Fenton et al (1990; 1991). The method involves measuring the specific activity of ^{226}Ra:^{210}Pb with direct alpha-spectrometry. Ages of fish were calculated on the basis of a single constant (linear) growth rate by the equation derived by Bennett et al (1982):

$$A = 1-(1-R)\ \frac{1-e^{-\lambda t}}{\lambda_p t}$$

where A= $(^{210}Pb:^{226}Ra)_t$ = activity at time t, R = $(^{210}Pb:^{226}Ra)_0$ = initial activity ratio at time of deposition, λ_p = decay constant for ^{210}Pb (0.03114 yr^{-1}).

Age composition

All length frequency data from trawls in each survey were combined to give a representative length frequency distribution at that time. Fish measured during the November 1990 survey were directly aged so the age composition could be determined directly. A sub-sample fish of each species from these cruises were aged.

Mortality

Total instantaneous mortality rates (Z) were estimated for each species from catch curve analysis. As fishing mortality was negligible during the past 10 years, total mortality equalled natural mortality (M). Natural mortality was also estimated by the formulae of Roff (1984) and Ralston (1987) where natural mortality were related to age at sexual maturity and the growth parameter K respectively. The formula of Roff (1984) was:

$$M = \frac{3Ke^{-Kt}}{1 - e^{-Kt}}$$

where t is age at sexual maturity and K is the von Bertalanffy growth parameter. Ralston (1987) found an empirical relationship between natural mortality and K such that $M = 2.06*K + 0.0189$.

Reproduction and spawning areas

In November 1990, the gonads from selected species were extracted, labelled and frozen for subsequent examination. In the laboratory, these were weighed, sectioned and stained with haematoxylin and eosin (Cyrus and Blaber 1984). Two slides per gonad were used to estimate the proportion of oocytes in each of 6 stages: 1 - Oogonia, 2 - Pre-vitellogenic oocytes, 3 - Yolk precursor, 4 - Red staining yolk, 5 - Completion of development, ripe , 6 - Atretic follicles, spent. The stage of the gonad was classified by the most advanced type of oocyte present (West 1990).

Data analysis

The length-at-age data was fitted to the re-parameterised von Bertalanffy growth curve of Francis (1988). This method has the advantage that the parameters estimated are independent and can be compared directly between species and populations.

All parameters were estimated by an iterative least-squares method (SAS NLIN procedure with the Marquardt option)(SAS, 1989). Vaughan and Kanciruk (1982) found that this procedure consistently showed the least bias in parameter estimates, converged rapidly and provided more precise estimates than standard linear techniques. Accuracy of the parameter estimates was also improved by increasing the sample size (Vaughan and Kanciruk, 1982). To reduce the number of iterations, initial estimates of the parameters were obtained from plots of length and age of each species at each site. A measure of goodness-of-fit was obtained by calculating an r^2 value from the residual and explained sums of squares derived from the least-squares regression.

Variation in age structure of each species between depth strata, area and bottom type were compared by analysis of variance (Sokal and Rohlf 1981).

Abiotic data

The abiotic data from the November-December 1990 survey in the GOC was used by Harris et al (Appendix 1) to examine the relationship between catch rates and environmental conditions.

SECTION 7 - RESULTS

Age and growth

Lutjanus malabaricus

Growth rates:

The growth curves expressing the best fit of length-at-age data from both sectioned otoliths and whole otoliths show that there are significant differences between these data in the estimated growth rates (Fig. 1). There were more rings found in sectioned otoliths than whole otoliths counts from the same fish. Radiometric ageing confirmed that the counts from whole otoliths better represented real ages than those from sectioned otoliths (Table 2). Based on the validation of whole otolith counts, L. malabaricus live for up to 9 yrs in the GOC (Table 3). There were no differences in growth rates between the sexes.

Age Composition:

The age frequency distributions of L. malabaricus (Fig 2) coincided well with the growth rates of fish from the Arafura sea (Edwards 1985). Small fish were mainly one year olds (modal length <1 year old) and large fish (>40 cm) were five years and older. In 1990, the survey fish population consisted mostly of two, three and four year olds (Fig. 2). This was more noticeable when compared to the age composition when there were fewer one year old fish (Fig. 2). In 1991 however, most of the population on the fishing grounds were new recruits less than one year old; there was an absence of two year olds; and the next major size mode corresponded to three year olds (Fig. 2).

Lutjanus erythropterus

Growth rates

Radiometric ages of L. erythropterus confirmed the ageing based on whole otoliths (Table 2). Lutjanus erythropterus grew to a smaller size than L. malabaricus in the GOC (Table 3). The oldest fish was 6+ years old at 431mm. Length-at-age data show that L. erythropterus grow faster than L. malabaricus of similar age but grow at a similar rate to L. russelli (Table 3). The von Bertalanffy growth parameters are given in Table 4.

Age Composition

Catches of L. erythropterus from the three cruises showed that the population in the deeper parts of the GOC was dominated by the 4+ age class (Fig. 3). The size composition of the catch in June 1990 when the codend mesh size was 10cm showed that the size and age range caught were narrow relative to other commercial species in the catch and suggested that this species schooled and these schools may be in single age classes.

Lutjanus sebae

Growth rates

There was a strong discrepancy between the age of L. sebae determined from sectioned and whole otoliths (Fig. 4). Radiometric ageing of L. sebae is still in progress so no data are available. Whole otolith ageing suggests that growth of L. sebae was similar to that of L. malabaricus. Sectioned ages suggest that fish collected in this study were approaching maximum size, although this species is known to grow to over 100cm (Allen and Swainston 1988). The growth curve based on whole otolith ages gave a L_{∞} of 148.3cm (Table 4) which is more consistent with available literature.

Age composition

Based on the assumption that whole otolith ageing is correct, the age structure of the L. sebae catches in the GOC was relatively evenly distributed among all age classes caught (Fig. 5). The oldest fish was 9+ years old and was 60.0cm long. In 1991, catches of L. sebae were dominated by 5+ fish (Fig. 5).

Lutjanus russelli

Growth rates

Growth rates based on whole otolith ages showed that L. russelli grew rapidly and continuously up to 4 years old (Table 3). These data did not conform to a growth curve of the von Bertalanffy shape as growth was linear (Fig. 6). A linear regression of length on age gave a growth equation of Length = 51.2 ± 2.3 * Age + 84.4 ± 6.8; r^2=0.78. Growth based on sectioned otoliths was much slower and the maximum age was 9 yrs (Table 4). Growth rates of L. russelli in aquaria was approximately 10cm a year (Smith et al 1991). This growth rate is more consistent with that found from ageing of whole otoliths.

Age composition

Catch rates for L. russelli were higher in November-December 1990 than at the same time in 1991. No juveniles were caught during the study and the dominant age class in 1990 was 2+. This differed in 1991 when more fish were 1+ (based on whole otolith ages)(Fig. 7).

Lethrinus lentjan

Growth rates:

Growth rates of L. lentjan based on whole otolith ageing were similar to other species examined. Growth did not conform to the von Bertalanffy growth equation and was linear over the size range examined (Table 3). The linear regression equation of the relationship between length and age was L = 41.9 ± 1.6*Age + 123.7 ± 4.7; r^2=0.74. The growth pattern based on sectioned ages did conform with the von Bertalanffy growth equation and the parameter estimates were similar to those found in other studies of this species (Table 4).

Age composition:

Based on whole otolith ageing data, L. lentjan from the GOC were mainly 1 and 2 year olds and large fish were greater than 4 years old. Sectioned otolith ageing found that fish lived up to 14 years (Fig. 8). Also one and 2 year olds (whole otolith age - O+) were not caught in the survey area. Their absence was not a result of the mesh size of the trawl as small L. malabaricus and D. pictum (similar shaped fish) were caught.

Lethrinus laticaudis

Growth rates:

Growth rates of L. laticaudis were similar to that of L. lentjan and other species in this study (Table 3). Fish grew to approximately 150 mm in their first year and reached the largest size caught (387 mm) by 5 years of age. This growth rate was somewhat slower than that found for north-west shelf fish by Morales-Nin (1989) (Table 4).

Age composition

The age distribution of L. laticaudis in the catch was dominated by one to two year olds in November 1990 (Fig. 9). In 1991, 1+ fish were not caught at all and the catch comprised more 2+ age class fish.

Diagramma pictum

Growth rates:

Diagramma pictum grew faster than other species based on whole otolith ages (Table 3). Fish reached 60cm in 8 years as opposed to 15 years suggested by sectioned otoliths. No independent ageing has been done on D. pictum. The only other study of this species also used sectioned otoliths to estimate age (Baillon and Kulbricki (1988) and found similar results to ours. The growth equation for D. pictum based on whole otolith ages suggest that maximum size is over 90 cm. This is similar to that recorded by Allen and Swainston (1988).

Age composition:

Based on whole otolith ages, the age structure of D. pictum in the GOC was mainly 3 and 4 year olds in November 1990. In 1991, the catches were dominated by 4 and 5 year olds but all age classes were represented in the catch (Fig. 10).

MORTALITY

Lutjanus malabaricus

Catch-curve analysis was used to estimate total mortality of L. malabaricus in November 1990 and November 1991. As total mortality equalled natural mortality in the GOC, these data provided an estimate of natural mortality. Assuming whole otolith ages were correct, natural mortality of L. malabaricus in both years was similar (M I 0.4)

(Figs. 11, 12). Estimates based on empirical relationships between natural mortality and growth also were similar to that obtained from the catch-curve analysis (Table 5). The estimates of natural mortality based on sectioned otolith ageing were also similar to those based on whole otolith ages.

Lutjanus erythropterus

All age-classes (based on whole otolith ages) of L. erythropterus were not equally catchable so catch-curve analysis could not be used to estimate total mortality. Empirical estimates suggest that natural mortality for L. erythropterus was between 0.34 - 0.70. If sectioned otolith ages are accurate, then the natural mortality of L. erythropterus would be similar to that of L. malabaricus (Table 5).

Lutjanus sebae

Total mortality of L. sebae was similar to that of L. malabaricus (Table 5). The natural mortality estimates of Ralston which use the relationship between natural mortality and the growth parameter K were much lower than other estimates.

Lutjanus russelli

Catch curve analysis could not be used to estimate total mortality of L. russelli when whole otolith ages were assumed (Table 5). Empirical estimates suggest that natural mortality is higher in this species and as expected give a shorter life-span than the other species examined. Even natural mortality estimates based on sectioned otolith ages were about twice those found for other Lutjanus in this study and higher than for the similar-sized L. vittus from the north-west shelf (Table 5).

Lethrinus lentjan

There was wide variation in the estimates of natural mortality of L. lentjan between catch curve estimates based on whole otolith ages and sectioned otolith ages (Table 5). The estimate based on sectioned otolith ageing was similar to that for large Lutjanus which is unlikely to be realistic given the large differences between species in maximum size. If the whole otolith ages are accurate, then natural mortality on L. lentjan was the highest of any species in this study.

Lethrinus laticaudis

Whole otolith age-classes of L. laticaudis were not representative so no catch curve analysis could be performed. The catch curve estimate based on sectioned otolith ages was similar to that of L. lentjan.

Diagramma pictum

Empirical estimates of natural mortality of D. pictum based on whole otoliths was higher than similar estimates for the large Lutjanus of similar size (e.g. L. malabaricus) (Table 5). The catch curve analysis based on sectioned otoliths gave higher estimates of natural mortality than other species.

REPRODUCTION AND SPAWNING AREAS

Lutjanus malabaricus

In November and December 1990, most fish were undergoing vitellogenesis and had mean gonadosomatic indices (GSI) of between 1.5% (stage 3) and 2% (stage 4) (Fig. 13e). There were few ripe fish but 15% of the fish examined were spent. Spent fish ranged from 30 cm to 64 cm so that the previous spawning had included, but was not restricted to, very large fish. The presence of large fish (45 cm) at stage 2 suggests that some fish may be resting from a previous spawning. The smallest mature fish was 32 cm and three years old. The highest GSI was 8.1% in a female in spawning condition. Fish in spawning condition were only found in the historical fishing ground in the northwestern GOC.

Lutjanus erythropterus

Most L. erythropterus examined (71%) were undergoing vitellogensis, similar to L. malabaricus, and these females had gonads that were in early stages of development (Stage 3). Fish over 35cm and 4 years of age (based on whole otolith ages) were sexually mature. No L. erythropterus were found with spent ovaries (Stage 6) in November 1990 but some (14%) had ovaries that were stage 2 which suggests that they may be resting from previous spawning.

Lutjanus sebae

Unlike other commercial species about 50% of fish were spent (Fig. 13f). The highest GSI was 3.0% and the smallest mature fish was 27 cm and three years old. The spent fish were only found in the northern part of the GOC similar to L. malabaricus.

Lutjanus russelli

Most female L. russelli examined from November and December 1990 had ripe gonads (55%; Stage 4) (Fig. 13g). Some fish were in spawning condition (8%) or had recently spawned (14%). Fish larger than 10cm had ripe gonads and these were all 1+ age class fish. The wide range of stages of gonad development at this time indicates that spawning is probably asynchronous in L. russelli.

Lethrinus lentjan

In November 1990 most fish (70%) were at a late stage of vitellogenesis (stage 4) and had a mean GSI of 1.1% (SE=0.05)(Fig. 13c). About 10% of fish were ripe and 16% were spent so that almost the entire population in the survey area were close to spawning or had recently spawned. The smallest mature fish was 16 cm and one year old. Some of the largest fishes (e.g. 48 cm) had yet to spawn. The highest GSI recorded was 3.0%.

Lethrinus laticaudis

Most fishes were either at an advanced stage of vitellogenesis or spent (Fig. 13b). The smallest mature fish from a sample of 20 fish was 24 cm and in their third year. The data indicated that fish were spawning in most parts of the GOC.

Diagramma pictum

Most fish in November (56%) were at a late stage of vitellogenesis (stage 4) and had a mean GSI of 1.4% (SE=0.8) (Fig. 13a). There were a few (5%) ripe fish that had a mean GSI of 2.14%. Spent fish ranged from 20 cm and in their third year (Fig. 13)(the smallest mature fish) to 46 cm and made up 25% of the fish examined. Some of the largest fishes (e.g. 63 cm, stage 4) had yet to spawn. The highest GSI recorded was 3.2%. Ripe fish were found throughout the GOC.

Relationship between reproductive condition and site, depth and bottom structure:

Data to examine these relationships for any species were collected during all three cruises in the GOC. Further sampling will be carried out in January 1993 and will give more seasonal variation in reproductive activity. From data already collected, there was little variation in reproductive condition among L. malabaricus caught during each cruise. Reproductively spent fish were only caught in the historical fishing grounds in the northwestern part of the gulf.

RELATIONSHIPS WITH BENTHIC STRUCTURE AND BENTHOS

All samples of infauna and epibenthos collected during November 1990 and 1991 have been examined and all species identified to the lowest taxonomic level possible.

The community structure, species density, spatial patterns of distribution of numerically dominant species of infauna has been completed (see Appendix 1: Long and Poiner 1993) and the abstract is attached (Appendix 2). A similar analysis of the community structure of the epibenthic fauna is currently being prepared for the special issue of Australian Journal of Marine and Freshwater Research **44** (3) next year (Long and Poiner in prep.).

The analysis of the degree of coupling between the fish and benthos will proceed after the epibenthic community structure has been determined. This will allow the fish-site groupings (Appendix 1: Blaber et al 1993) to be correlated with the benthos site-groupings.

The other aspect of the coupling between fish and benthos to be examined was the identification of key benthic prey and the degree of prey selectivity and its effect on fish distributions. The diets of abundant predatory fishes in the GOC has been examined (Appendix 1: Salini et al 1993). Analysis of prey selectivity and the identification of key benthic prey is in progress.

SECTION 8 - DISCUSSION

Growth

One of the major findings of this study that will impact on the utility of the results has been the discrepancy in ring counts between whole and sectioned otoliths. This variation increased with size and age and the relationship between the two ring count methods was linear. This relationship was not constant between species. Radiometric ageing was used to resolve the problem for three of the longer-lived species. It found that radiometric ages were consistent with the whole otolith ages for all species (Table 2). Whether the same interpretation holds true for the other species is difficult to determine. The growth parameter estimates on most of these studies of related species are more consistent with the whole otolith ageing. Further studies with other radio-active isotopes of shorter half-lifes such as ^{210}Po:^{210}Pb could be used to resolve the true ages for fish 2 - 10 yrs old.

There are very few studies of growth of tropical Lutjanus and Lethrinus from the Indo-Pacific. There have been several studies of growth of L. malabaricus from northern Australia (Lai and Liu 1979; Chen et al 1984) and elsewhere (Lai and Liu 1974). These studies used ring counts in vertebrae (Lai and Liu 1974; 1979) and sectioned otoliths (Chen et al 1984) to estimate age. All studies found similar results to that obtained from whole otolith ageing in this study. Lutjanus malabaricus live up to 9 years and reach a maximum size of 65cm. Previous studies differed from this study in the estimates of the von Bertalanffy growth parameters L_∞ and K (Table 4). This could have major impacts on age-structured fishery models (e.G. yield-per-recruit) that use these parameters to estimate optimal yield.

There have been three other studies of L. lentjan growth which varied in the estimates of maximum size and age attained (see Table 4). All studies tended to support the ageing based on whole otoliths as the maximum age found was 7 yrs in India by Toor (1968). The study of Morales-Nin (1989) found L. laticaudis (as L. choerorynchos) lived to 5 years. This was the maximum age found, based on whole otolith counts.

Unlike other species, the growth rate estimates for D. pictum that were based on sectioned otoliths were similar to the other study of this species (Table 5) and suggests that the sectioned otolith ages may be more representative of the real age.

Mortality

Natural mortality (M) estimates of the species in this study were similar to that estimated in other studies of related species (e.g. Ralston 1987). Related species of similar size such as L. malabaricus and L. sebae had similar estimates of natural mortality. However, there was some variation in the results from empirical estimation methods. These use the relationship between natural mortality and the growth parameter K. This parameter can vary significantly between studies of the same species of similar growth rates (see above for example) so results using these methods should be treated with caution. Vetter (1988) discussed the validity of the assumptions of the methods commonly used to estimate M. He found that there was no single method to reliably estimate this parameter in fishes. By using several methods, one can hopefully generate a confidence region for M for a species.

There have been no previous estimates of M for any of the species in this study except L. malabaricus. Hence the data will be very useful in fisheries models and will greatly enhance confidence in the models applied to this multi-species fishery. They will increase the reliability of the models that rely on input values of M, such as yield-per-recruit.

Reproduction and spawning areas

The limited reproductive data collected from fish caught in the November-December 1990 cruise was very useful in establishing several aspects of the reproductive biology of these species. There is little reproductive information on any of these species in

Australia and only the study of Loubens (1980a) from New Caledonia was available for comparison.

The study showed that the large lutjanids that make up the bulk of the catch from this fishery reach sexual maturity at 30-35cm and 4 years of age. The lethrinids became sexually mature at smaller sizes and earlier (2 yrs). These data will be useful when looking at mesh selection of trawl nets and will help in the monitoring of the effects of fishing on the reproductive population.

Histological data showed that each species varied in their state of reproductive development at that time. Most L. sebae had just spawned while most other species had mainly ripe gonads. This indicates that they were in the process of spawning in the near future. Other results from the histology of the gonads include circumstantial evidence that these species are all multiple spawners suggesting that each spawns asynchronously during the warmer months and has more than a single spawning each year. This conclusion was drawn from the presence of ova in more than one stage of development in each ovary.

Relationships with benthic structure and benthos

The data are available to describe the benthic structure of the GOC and the results are expected in the near future. As the abstract in Appendix 2 indicates, infauna distributions are related to sediment grain-size. This feature of the seabed of the GOC has a gradual pattern of increasingly smaller grain-size across the gulf in a southeast-northwest direction. Muddier sediments were found in the northwestern GOC. The epibenthos is expected to show a trend that has a similar pattern (Long pers. comm.).

Once the community structure of the epibenthos is established the relationship to the pattern in fish distribution can be explored. Key benthic prey can then be related to their contribution to the diets of the commercial species (Appendix 1 - Salini et al 1993).

SECTION 9 IMPLICATIONS AND RECOMMENDATIONS

1. All species studied live less than 15 years. All grew at similar rates up to 3 years of age.

2. Except for three species of Lutjanus, there is conflict in the accurate interpretation of otolith ageing data. It is recommended that other independent methods be used or developed (such as radiometric methods) to answer this problem.

3. Natural mortality estimates for the large lutjanids were included in the annual northern demersal fish stock assessment workshop of 1992 to estimate the optimal yield from this fishery. Future assessments can now be expanded to include the other species that form a significant part of the catch and permit more accurate estimates of the total yield.

4. The reproductive data shows that each species has a protracted spawning season during the warmer months. Most species spawned throughout the GOC where they occurred, although spent L. malabaricus were only found in the north-western part of the GOC. If a large fishery were to develop that targeted spawning aggregations of this species the impact of fishing on the stocks would increase significantly.

5. As most of the large species were sexually mature at 30cm, trawl codend mesh sizes over 10cm should ensure that most immature fishes escape the net. Reductions in trawl codend mesh size may impact on stocks by causing recruitment overfishing. It is recommended that mesh sizes remain at current sizes.

SECTION 10 INTELLECTUAL PROPERTY

There was no commercially significant development that arose as a result of this study and no patents have been applied for.

SECTION 11 TECHNICAL SUMMARY

1. This study has highlighted the use of radiometric ageing as a useful tool in the ageing of fishes. This method has only been used previously to age fish long-lived fish (e.g. Orange Roughy). This is the first time it has been applied to tropical species that live less than 10 years.

2. There is potential for inaccurate ageing if only one technique is relied on, without adequate validation. Marginal increment analysis does not validate the number of rings counted in the otolith.

3. The the community of large fishes in the GOC live to similar ages to those of related species in other tropical areas.

4. The historical fishing area in the northwestern GOC may be a spawning ground for L. malabaricus.

5. Spawning by commercial fish species in the GOC is not synchronised and is protracted during the warmer months.

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Legends for Tables

Table 1. Abiotic parameters at the 105 demersal trawl shots in the Gulf of Carpentaria during November-December 1990

Table 2. Comparison of the number of rings detected in sectioned and whole otolish counts and the age estimated by radiometric methods

Table 3. Length-at-age (± s.e.) of seven species of fish important in the demersal trawl fishery in the Gulf of Carpentaria based on ages from whole otoliths

Table 4. Von Bertalanffy growth parameters of various tropical Lutjanids, Lethrinids and Diagramma pictum from northern Australia and within their range

Table 5. Total mortality and naturality of Lutjanids and Lethrinids from northern Australia by catch curve analysis (CC) and the empirical formulae of Roff (1984) and Ralston (1987)

Table 1. Abiotic parameters at the 105 demersal trawl shots in the Gulf of Carpentaria during November-December 1990.

Physical parameter	N	mean	SD	minimum	maximum
Depth (m)	105	46.13	10.71	15.5	48.40
Time (1 = day, 2 = night)	105	1.53	0.50	2.00	2.00
Salinity (ppt)					
Bottom	101	35.34	0.33	35.27	36.55
Difference (surface-bottom)	101	0.05	0.26	0.03	1.40
Temperature (°C)					
Bottom	101	26.78	1.58	26.71	30.80
Difference (surface-bottom)	101	2.82	1.78	2.72	5.77
Sediment (%)					
Gravel	105	6.46	5.62	5.97	30.45
Mud	105	47.44	24.75	43.30	97.40
Sand	105	46.08	22.35	48.63	89.21
Turbidity (NTU)					
Bottom	103	1.57	0.70	1.50	3.80
Mid-water	104	0.99	0.43	0.95	2.60
Difference (surface-bottom)	102	0.64	0.64	0.50	3.35

Table 2: Comparison of the number of rings detected in sectioned and whole otolith counts and the age estimated by radiometric methods.

Species	Sectioned count	Whole otolith count	Radiometric Age (yrs)
L. malabaricus	3	1 - 2	< 1.8 (95% conf.)
	6	4	<4.6 (95% conf.)
	6	3	6.3 ± 4.0
	6	3	3.0 ± 0.7
	13	9	3.0 ± 1.0
	14	6	5.6 ± 0.9
	19	8	8.8 ± 2.1
L. erythropterus	3	3	5.1 ± 1.5
	6	3 - 4	2.8 ± 1.5
L. sebae			

Table 3: Length-at-age (± s.e.) of seven species of fish important in the demersal trawl fishery in the Gulf of Carpentaria based on ages from whole otoliths.

Species	Age (yrs)										
	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	N
Lutjanus											
L. malabaricus	86 ± 7	146 ± 1	240 ± 5	293 ± 2	338 ± 3	381 ± 3	413 ± 2	443 ± 3	467 ± 8	501 ± 11	897
L. erythropterus	-	177 ± 3	261 ± 3	321 ± 5	380 ± 3	410 ± 3	431 ± 0	-	-	-	187
L. sebae	122 ± 3	169 ± 4	226 ± 5	281 ± 4	341 ± 3	393 ± 5	444 ± 8	473 ± 7	563 ± 12.5	600 ± 0	159
L. russelli	105 ± 0	186 ± 3	231 ± 2	284 ± 5	395 ± 0	-	-	-	-	-	150
Lethrinus											
L. lentjan	147 ± 12	207 ± 2	244 ± 2	288 ± 4	337 ± 5	-	-	-	-	-	279
L. laticaudus	109 ± 2	203 ± 3	238 ± 2	282 ± 5	352 ± 5	387 ± 1	-	-	-	-	223
Diagramma pictum	123 ± 5	203 ± 6	276 ± 4	325 ± 6	409 ± 3	463 ± 5	554 ± 9	561 ± 6	574 ± 0	-	275

Table 4: Von Bertalanffy growth parameters of various tropical Lutjanids, Lethrinids and Diagramma pictum from northern Australia an within their range (W = whole otoliths; S = sectioned otoliths; V = vertebrae; U = urohyal; Sc = scales).

Species	Locality	Method	K	L_∞	Maximum Age	Reference
Lutjanus						
L. malabaricus	Arafura Sea	V	0.17	707	10	Edwards (1985)
		V	0.12	790	8	Lai and Lui (1979)
	Gulf of Carpentaria	W	0.21	591	9	present study
		S	0.15	565	19	present study
	N.W. Australia	V	0.13	768	8	Lai and Lui (1979)
	S. China Sea	V	0.14	790	11	Lai and Lui (1974)
	Vanuatu	S	0.31	-	-	Brouard and Grandperrin (1984)
L. erythropterus	Gulf of Carpentaria	W	0.35	521	6	present study
		S	0.19	467	12	present study
L. sebae	Gulf of Aden	Sc	0.16	660	11	Druzhinin and Filatova (1980)
	Gulf of Carpentaria	W	0.06	1483	9	present study
		S	0.08	657	16	Present study
L. russelli	Gulf of Carpentaria	W	0.36	314	4	present study
		S	0.25	356	9	present study
L. vittus	N.W. Australia	U	0.22	346	8	males; Davis and West (1992)
		U	0.37	267	7	females; Davis and West (1992)
Lethrinus						
L. lentjan	Gulf of Carpentaria	W	-	-	4	present study
		S	0.28	297	14	present study
	India	W	0.27	492	5	Toor (1964)
	New Caledonia	S	0.33	292	-	Loubens (1980b)
	Red Sea	Sc	0.29	339	7	Wassef (1991)
L. laticaudis	Gulf of Carpentaria	W	0.20	575	5	present study
		S	0.56	266	11	present study
	N.W. Australia	S	0.43	326	5	Morales-Nin (1989)
Diagramma pictum	Gulf of Carpentaria	W	0.13	931	8	present study
		S	0.27	534	15	present study
	New Caledonia	S	0.21	666	12+	Baillon and Kulbicki (1988)

Table 5: Total mortality and natural mortality of Lutjanids and Lethrinids from northern Australia by catch curve analysis (CC) and the empirical formulae of Roff (1984) and Ralston (1987) (W = whole otolith ageing; S = sectioned otolith ageing; U = urohyal ageing).

Species	Method	Total mortality	Natural mortality CC	Roff	Ralston
Lutjanus					
L. malabaricus	W	0.42 ± 0.10	0.42 ± 0.10	0.34	0.45
	S	0.39 ± 0.04	0.39 ± 0.04	0.31	0.33
L. erythropterus	W	-	-	0.34	0.70
	S	0.39 ± 0.06	0.39 ± 0.06	0.27	0.41
L. sebae	W	0.51 ± 0.12	0.51 ± 0.12	0.66	0.14
	S	0.44 ± 0.09	0.44 ± 0.09	0.32	0.18
L. russelli	W	-	-	2.49	0.76
	S	0.77 ± 0.18	0.77 ± 0.18	1.16	0.53
L. vittus[1]	U	0.98 ± 0.08	-	0.66	0.56
Lethrinus					
L. lentjan	W	1.37 ± 0.29	1.37 ± 0.29	-	-
	S	0.43 ± 0.06	0.43 ± 0.06	1.12	-
L. laticaudis	W	-	-	0.73	-
	S	0.45 ± 0.09	0.45 ± 0.09	0.20	-
Diagramma pictum	W	-	-	0.82	-
	S	0.55 ± 0.08	0.55 ± 0.08	1.13	-

1. Davis and West (1992)

Captions to figures

Fig. 1: The growth curves of L. malabaricus based on whole otolith ring counts (closed circles) and sectioned otoliths (open squares). The vertical bars represent the range in length at age.

Fig. 2: The age structure of L. malabaricus catches during (a) June 1990, (b) November-December 1990 and (c) November-December 1991 based on whole otolith ageing.

Fig. 3: The age structure of L. erythropterus catches during (a) June 1990, (b) November-December 1990 and (c) November-December 1991 based on whole otolith ageing.

Fig. 4: The growth curves of L. sebae based on whole otolith ring counts (closed circles) and sectioned otoliths (open squares). The vertical bars represent the range in length at age.

Fig. 5: The age structure of L. sebae catches during (a) November-December 1990 and (b) November-December 1991 based on whole otolith ageing.

Fig. 6: The growth curves of L. russelli based on whole otolith ring counts (closed circles) and sectioned otoliths (open squares).

Fig. 7: The age structure of L. russelli catches during (a) November-December 1990 and (b) November-December 1991 based on whole otolith ageing.

Fig. 8: The age structure of L. lentjan catches during (a) November-December 1990 and (b) November-December 1991 based on whole otolith ageing.

Fig. 9: The age structure of L. laticaudis catches during (a) November-December 1990 and (b) November-December 1991 based on whole otolith ageing.

Fig. 10: The age structure of D. pictum catches during (a) November-December 1990 and (b) November-December 1991 based on whole otolith ageing.

Fig. 11: Catch curve and natural mortality of L. malabaricus in December 1990.

Fig. 12: Catch curve and natural mortality of L. malabaricus in December 1991.

Fig. 13: The reproductive stages and gonadosomatic index (as % x 10) of commercial fishes in November-December 1990.

Fig. 1

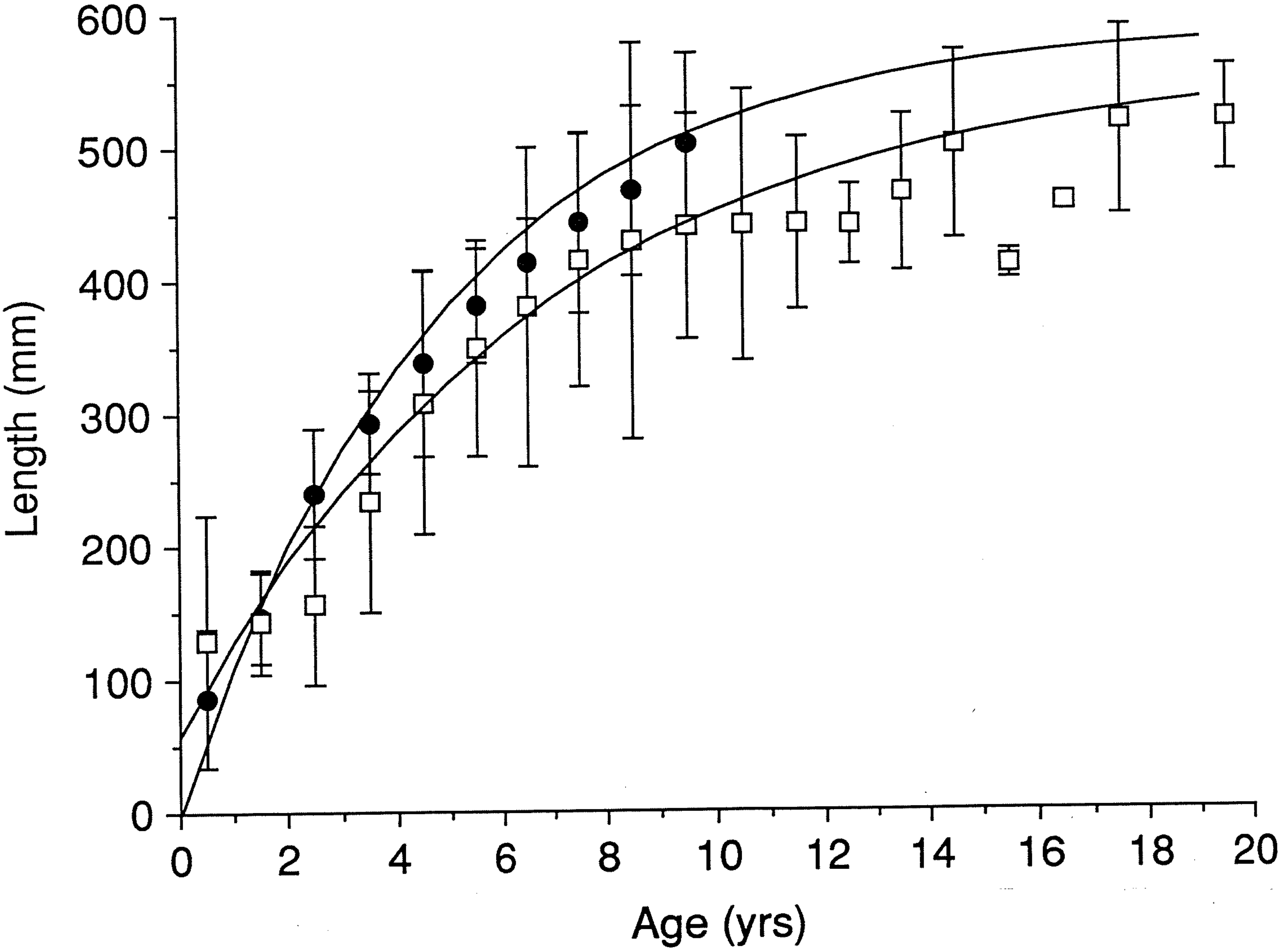

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Fig. 2a

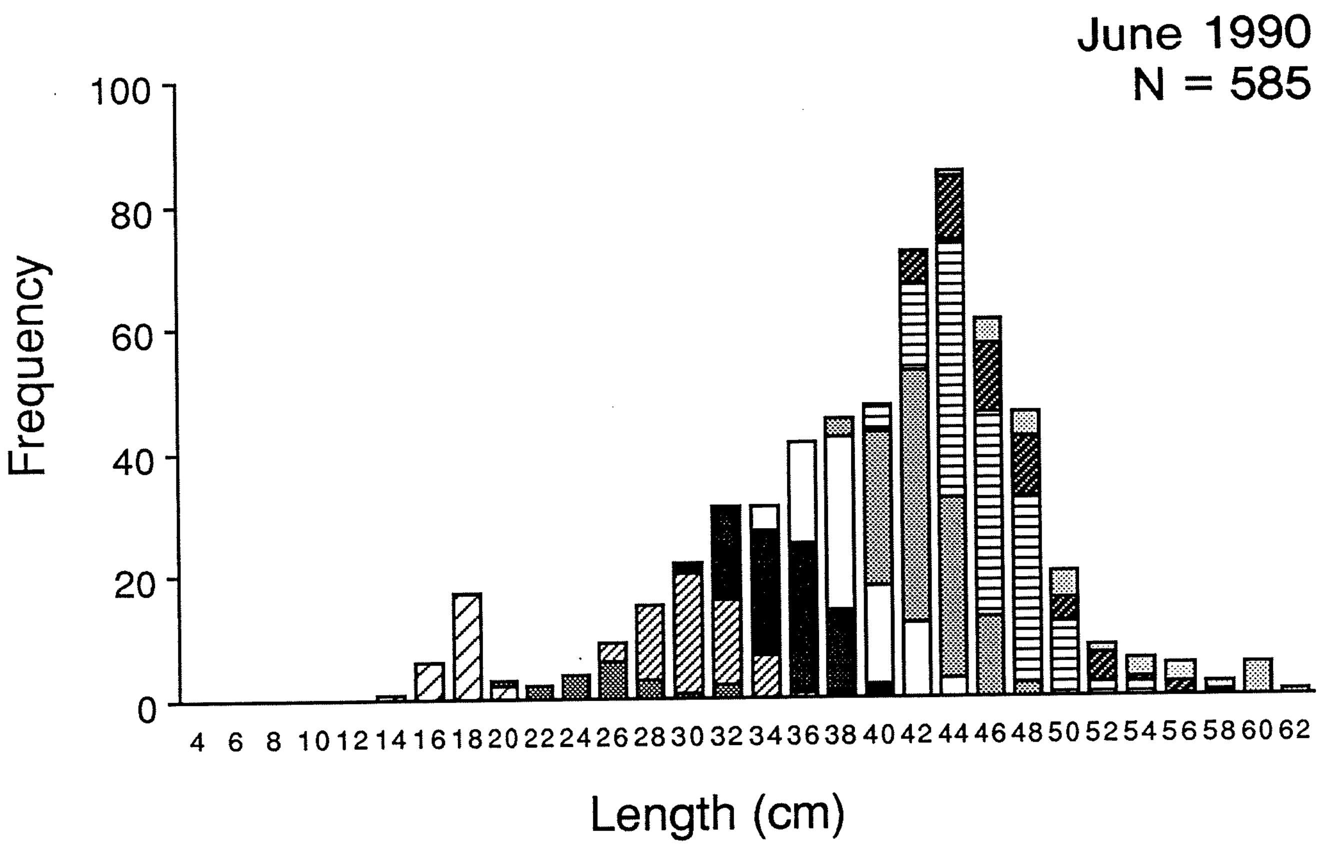
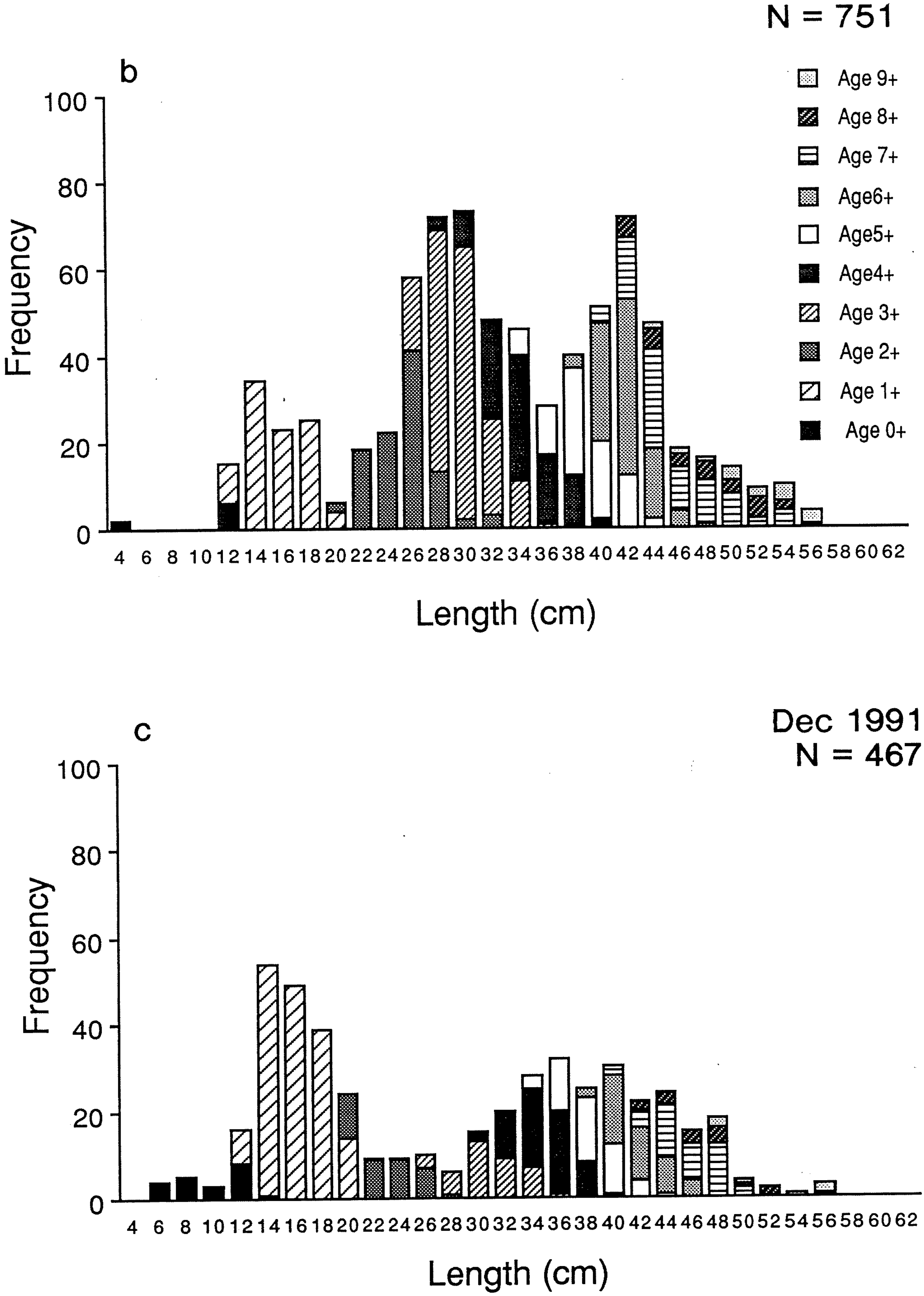

June 1990
N = 585
Frequency
100
80
60
40
20
0
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62
Length (cm)

Fig. 2



Dec 1990
N = 751
b
Age 9+
Age 8+
Age 7+
Age6+
Age5+
Age4+
Age 3+
Age 2+
Age 1+
Age 0+
Frequency
0
20
40
60
80
100
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62
Length (cm)
c
Dec 1991
N = 467
Frequency
0
20
40
60
80
100
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62
Length (cm)

Fig. 3a

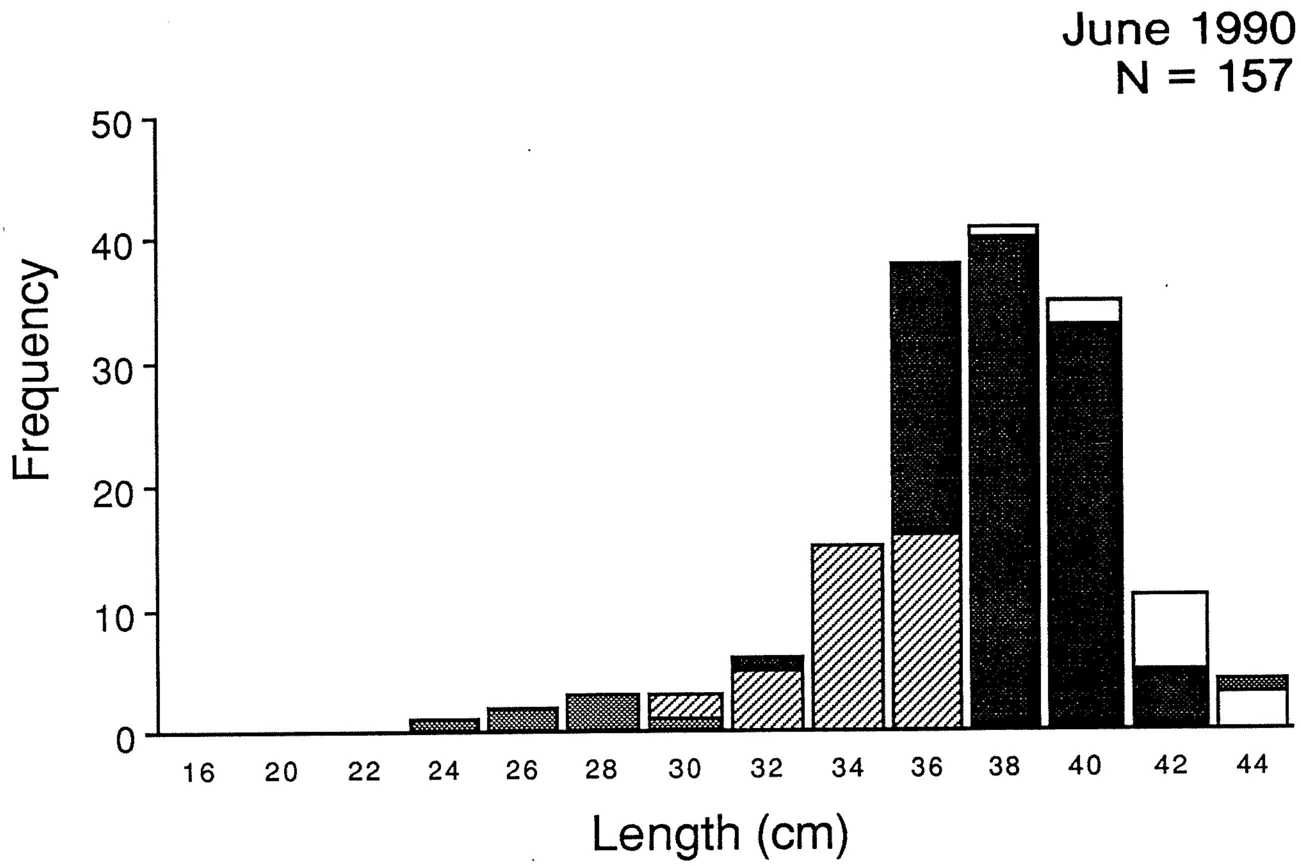
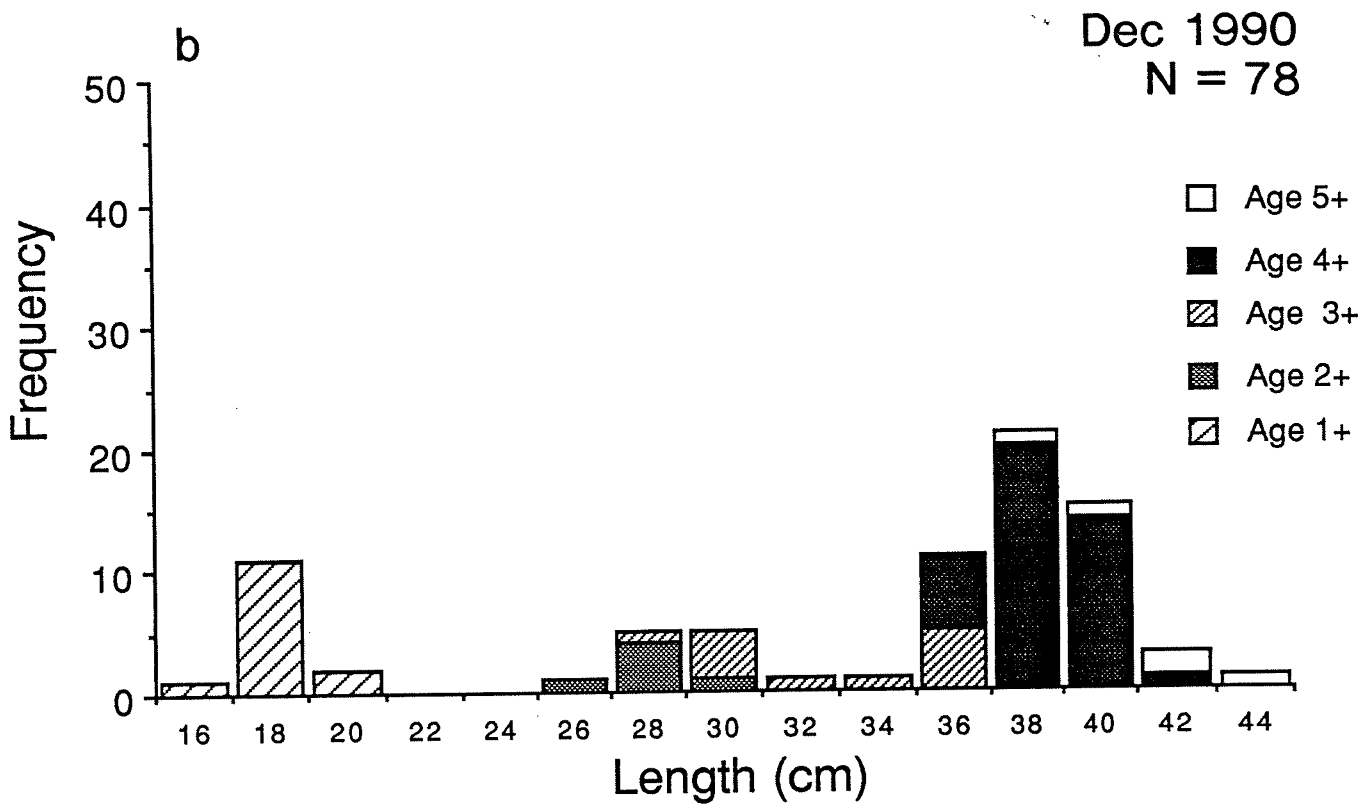

June 1990
N = 157
50
40
30
20
10
0
Frequency
16
20
22
24
26
28
30
32
34
36
38
40
42
44
Length (cm)

Fig. 3


b
Dec 1990
N = 78
Frequency
50
40
30
20
10
0
Age 5+
Age 4+
Age 3+
Age 2+
Age 1+
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
Length (cm)

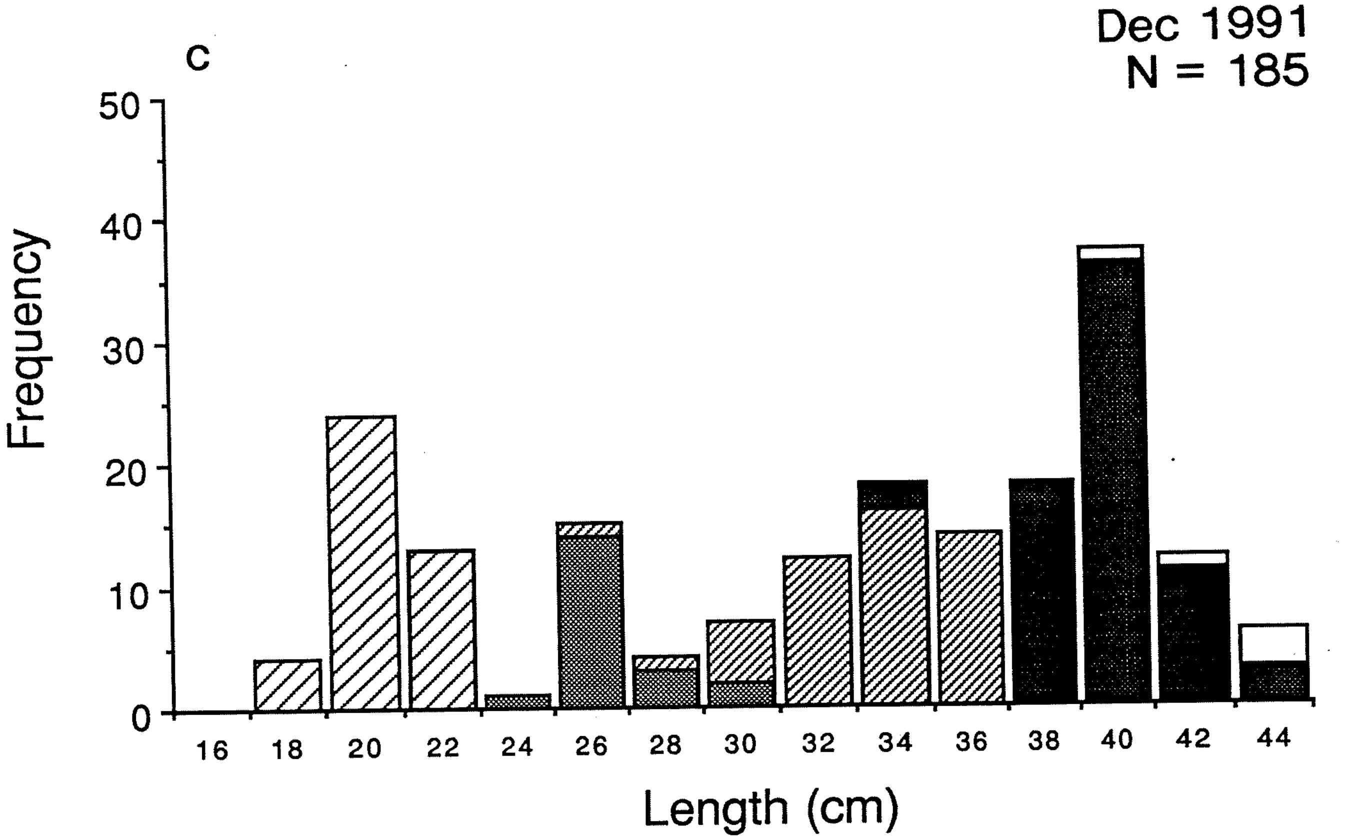

c
Dec 1991
N = 185
Frequency
50
40
30
20
10
0
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
Length (cm)

Fig. 4

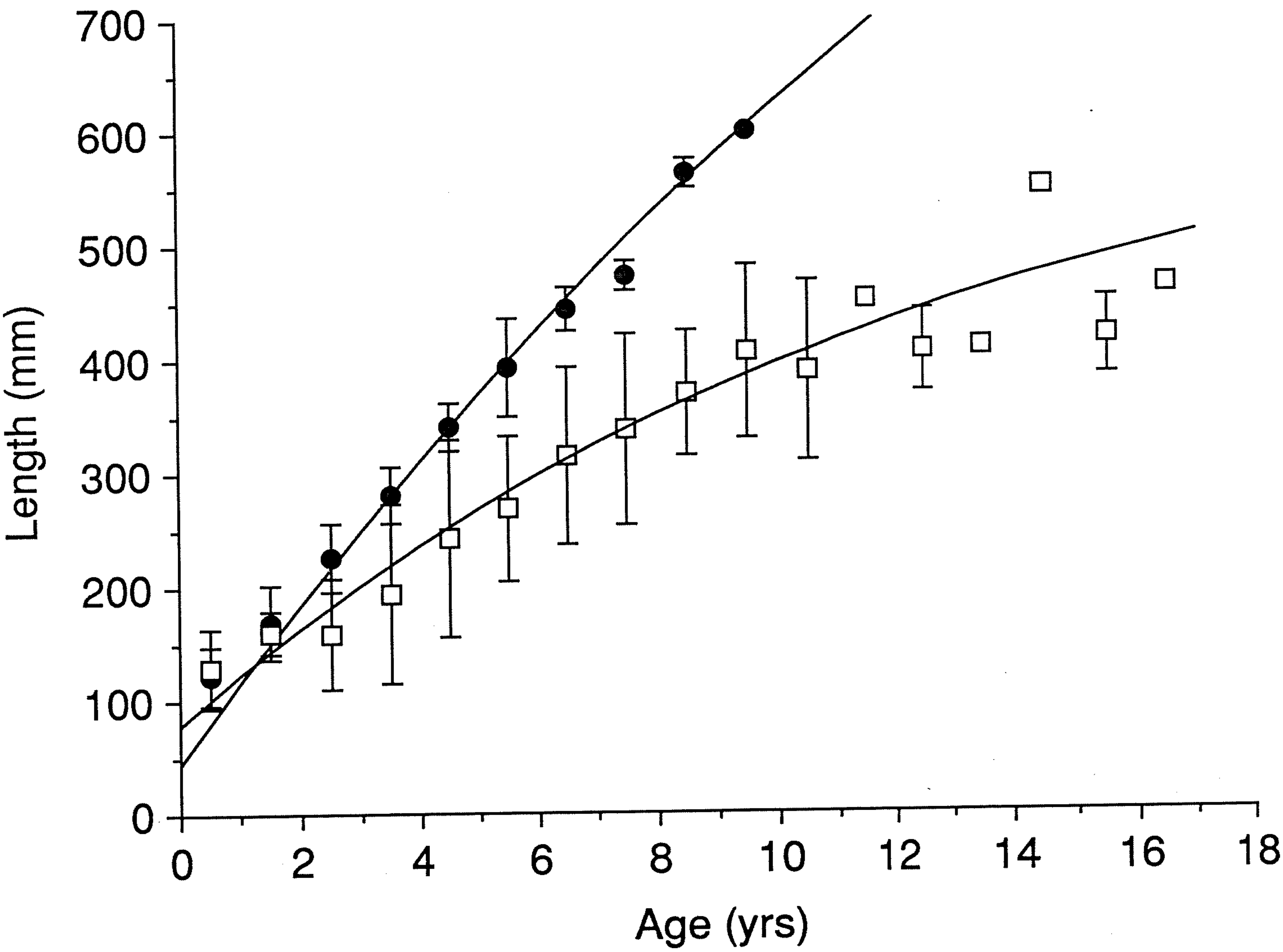


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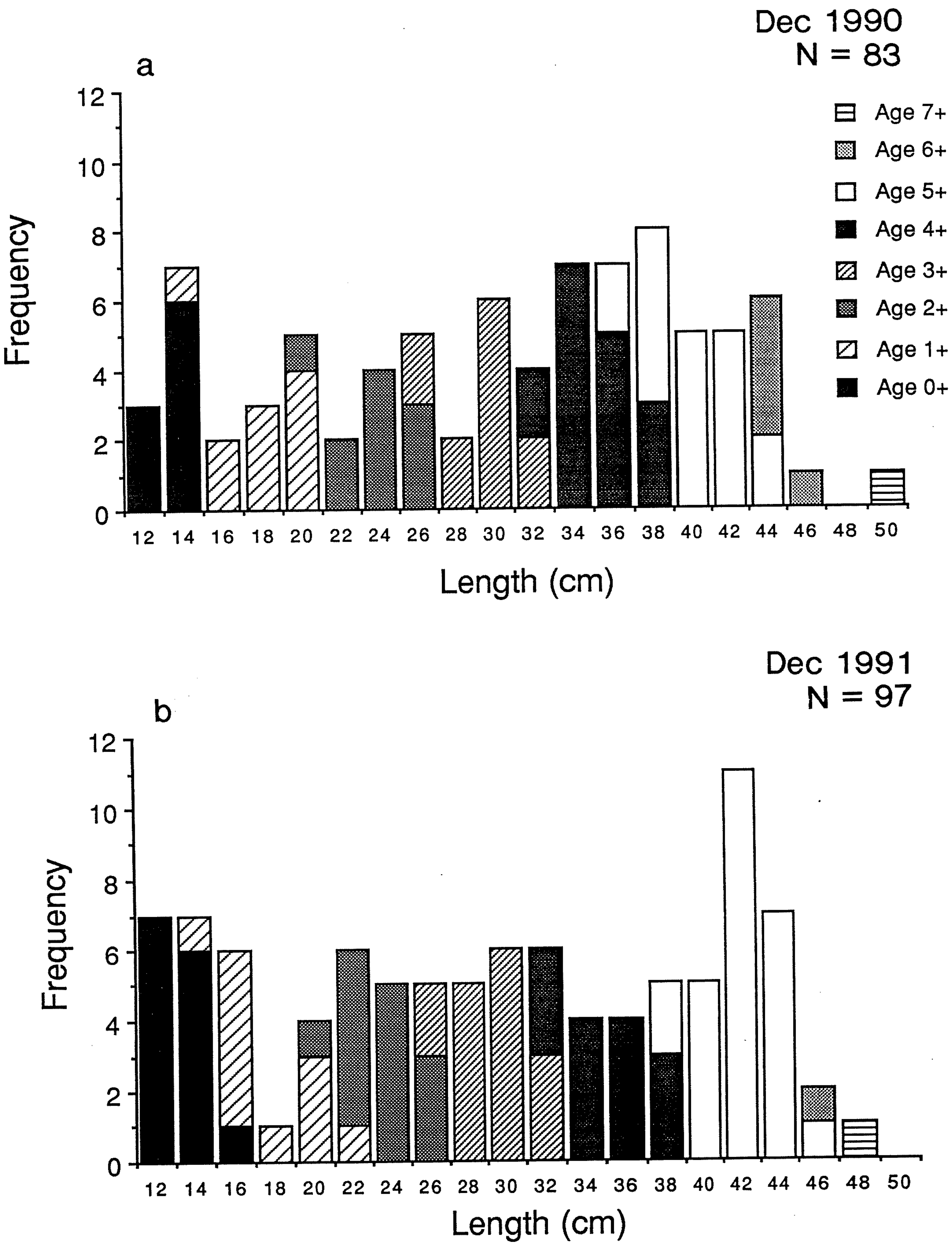
Fig. 5



Dec 1990
N = 83
a
Age 7+
Age 6+
Age 5+
Age 4+
Age 3+
Age 2+
Age 1+
Age 0+
Frequency
Length (cm)
Dec 1991
N = 97
b
Frequency
Length (cm)

Fig. 6

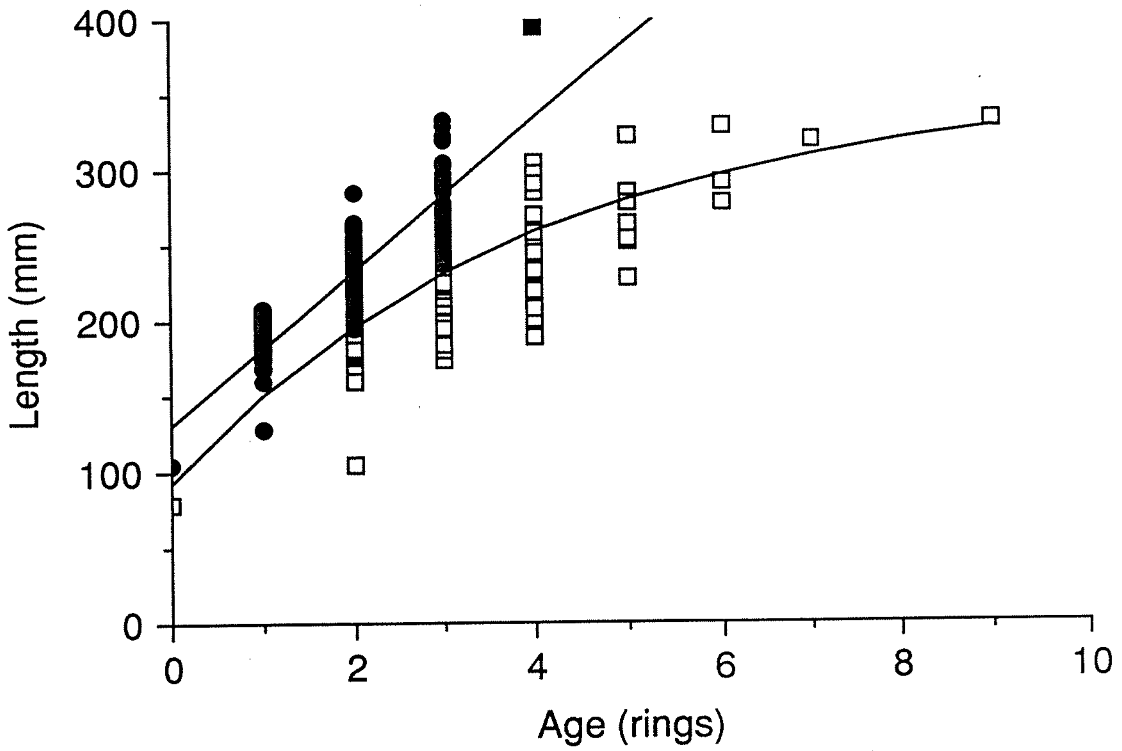
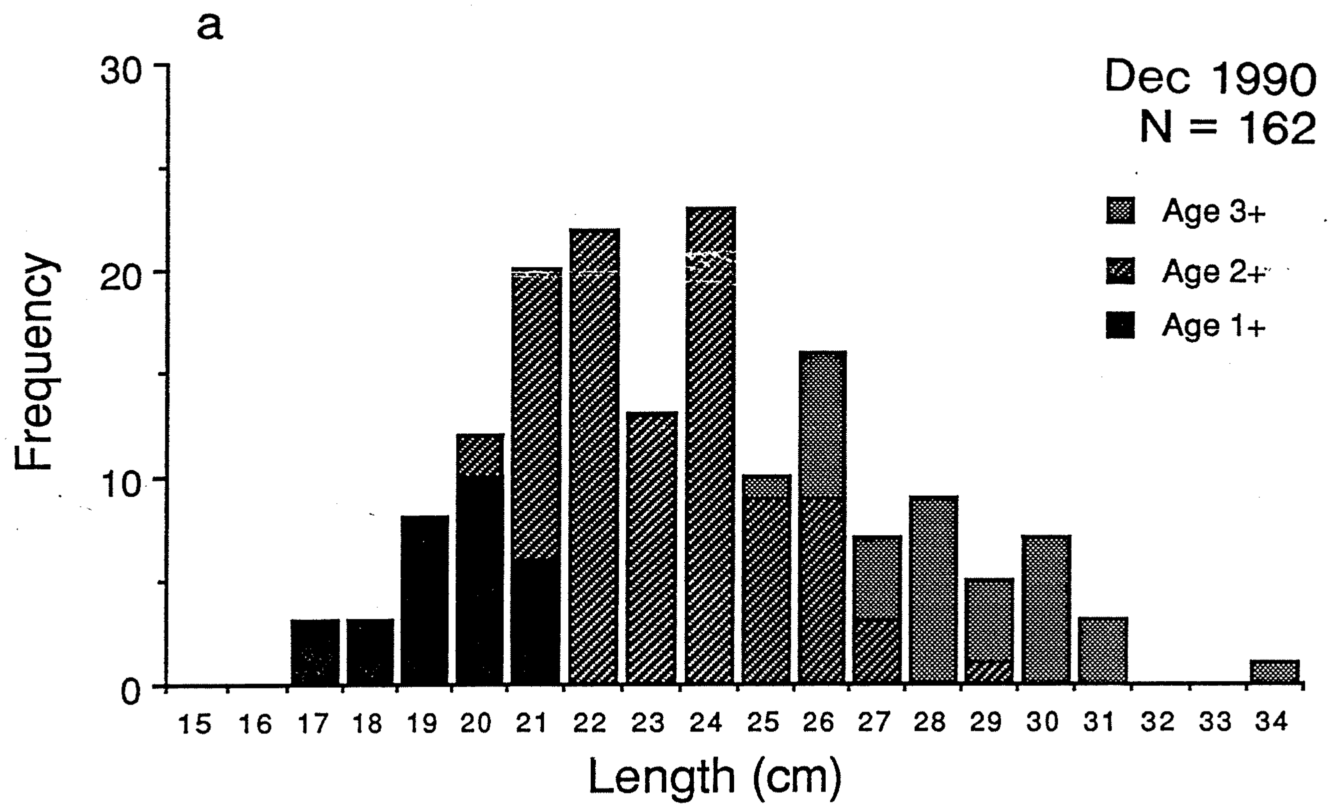
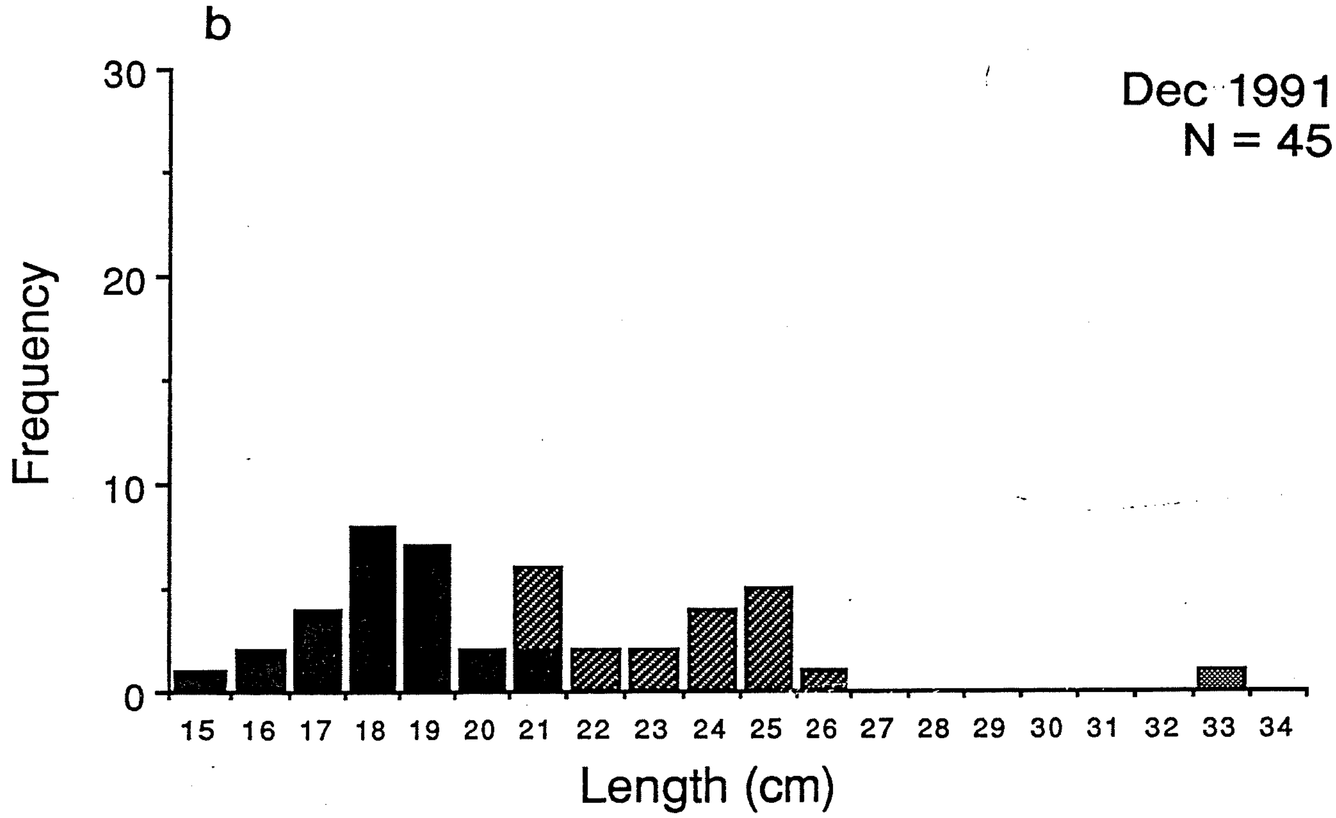


Fig. 7



a
Dec 1990
N = 162
Age 3+
Age 2+
Age 1+
Frequency
0
10
20
30
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Length (cm)



b
Dec 1991
N = 45
Frequency
0
10
20
30
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Length (cm)

Fig. 8

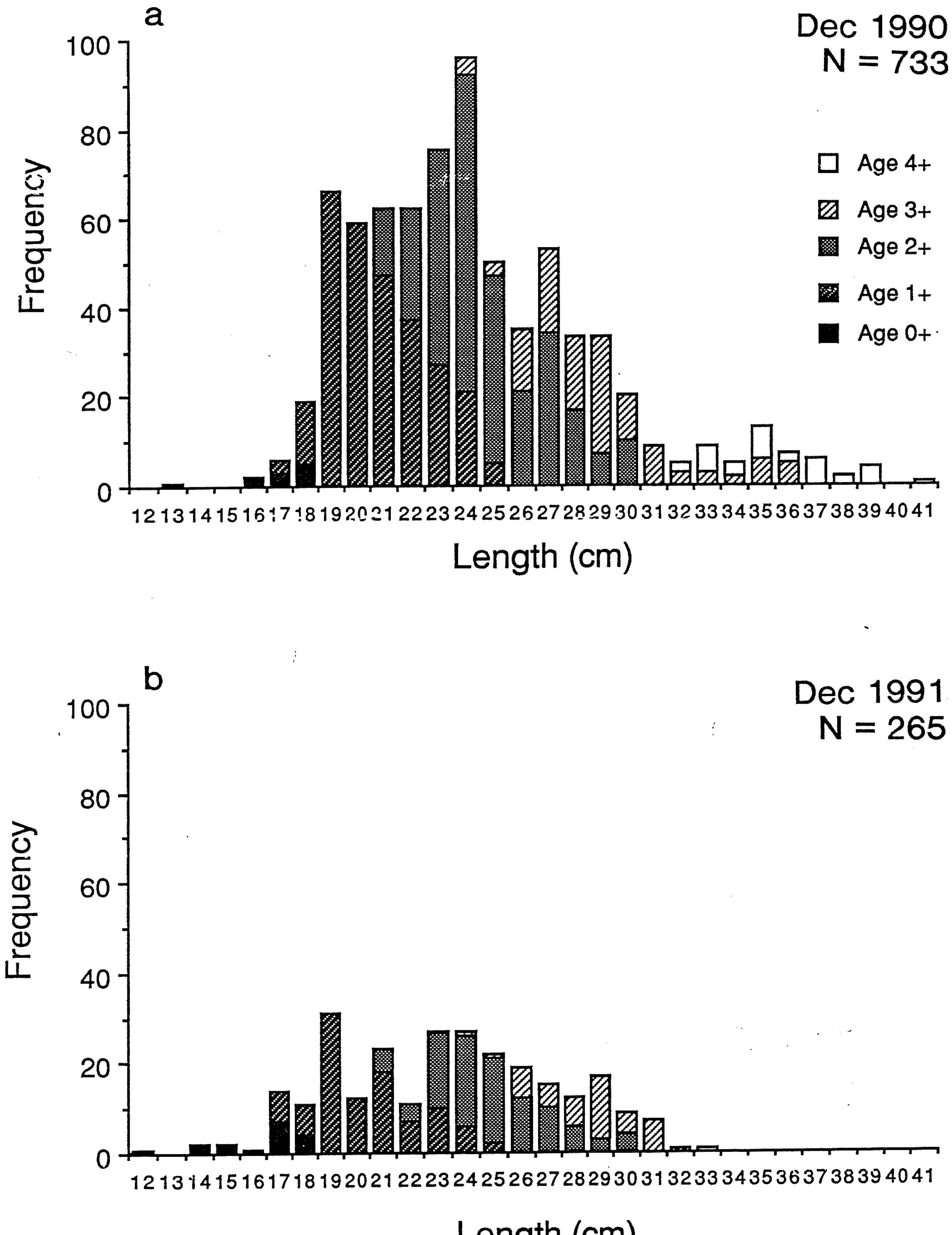

a
Dec 1990
N = 733
Frequency
Age 4+
Age 3+
Age 2+
Age 1+
Age 0+
Length (cm)
b
Dec 1991
N = 265
Frequency
Length (cm)

Fig. 9

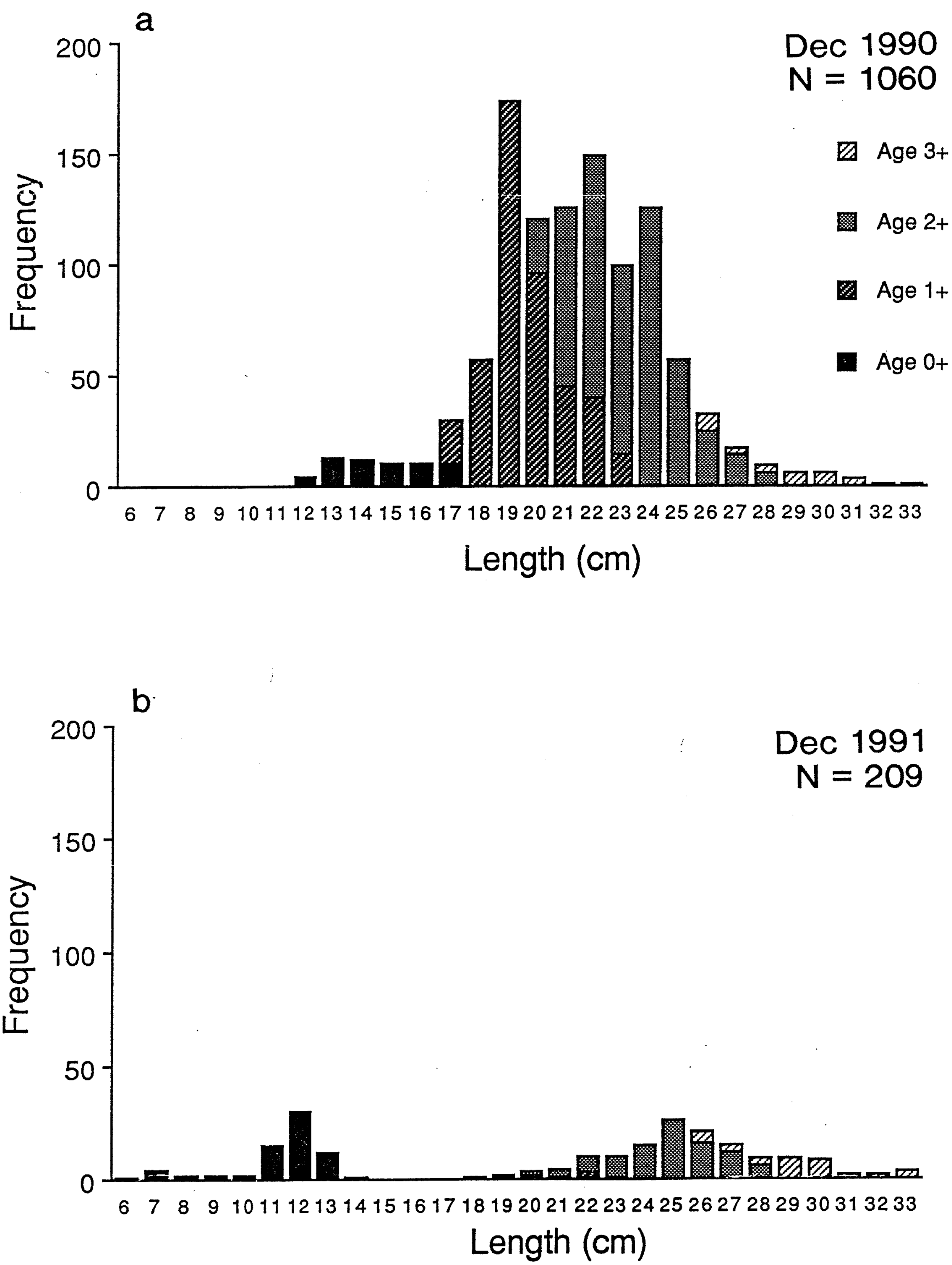

a
Dec 1990
N = 1060
Age 3+
Age 2+
Age 1+
Age 0+
Frequency
0
50
100
150
200
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Length (cm)
b
Dec 1991
N = 209
Frequency
0
50
100
150
200
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Length (cm)

Fig. 10

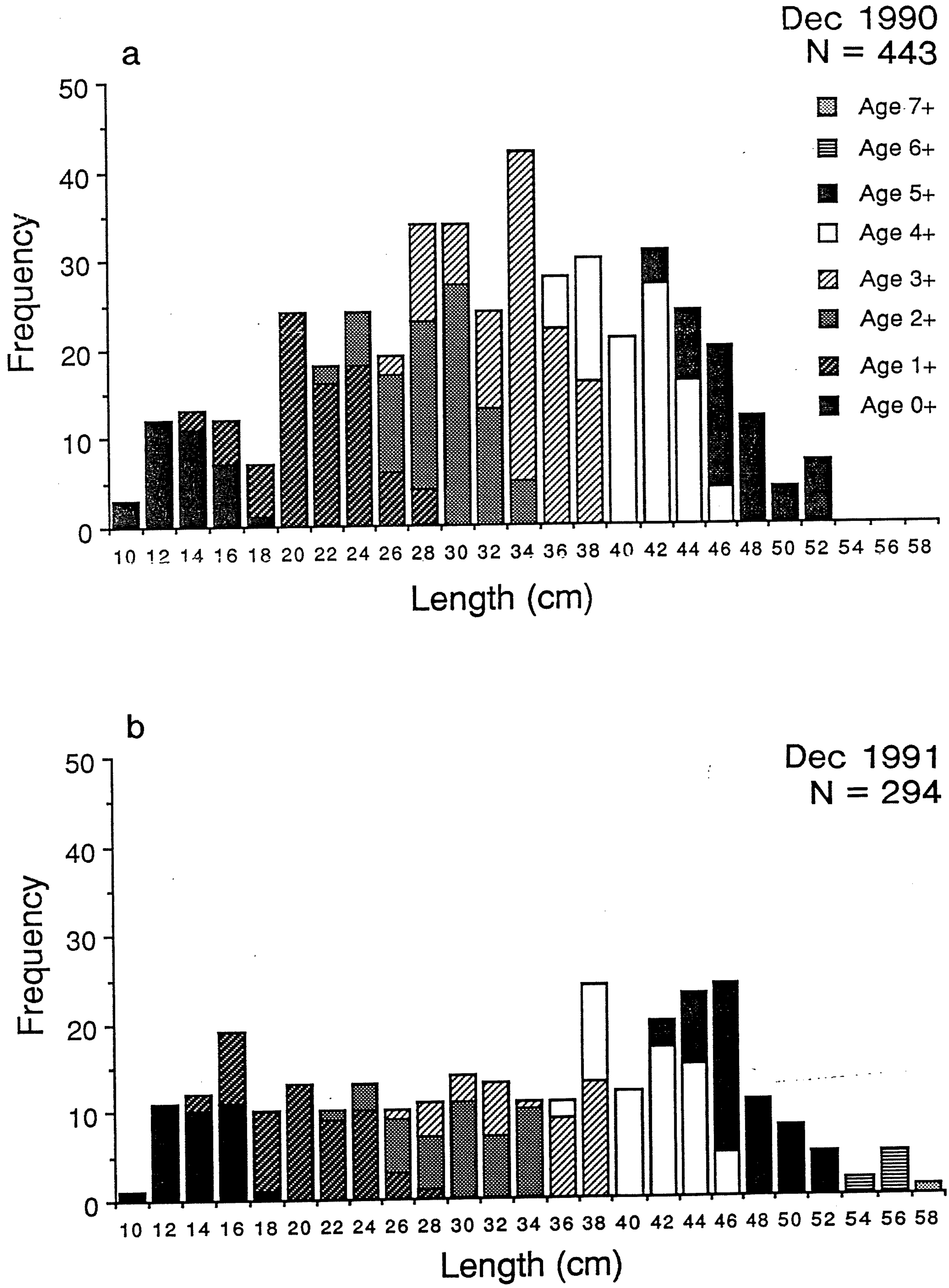
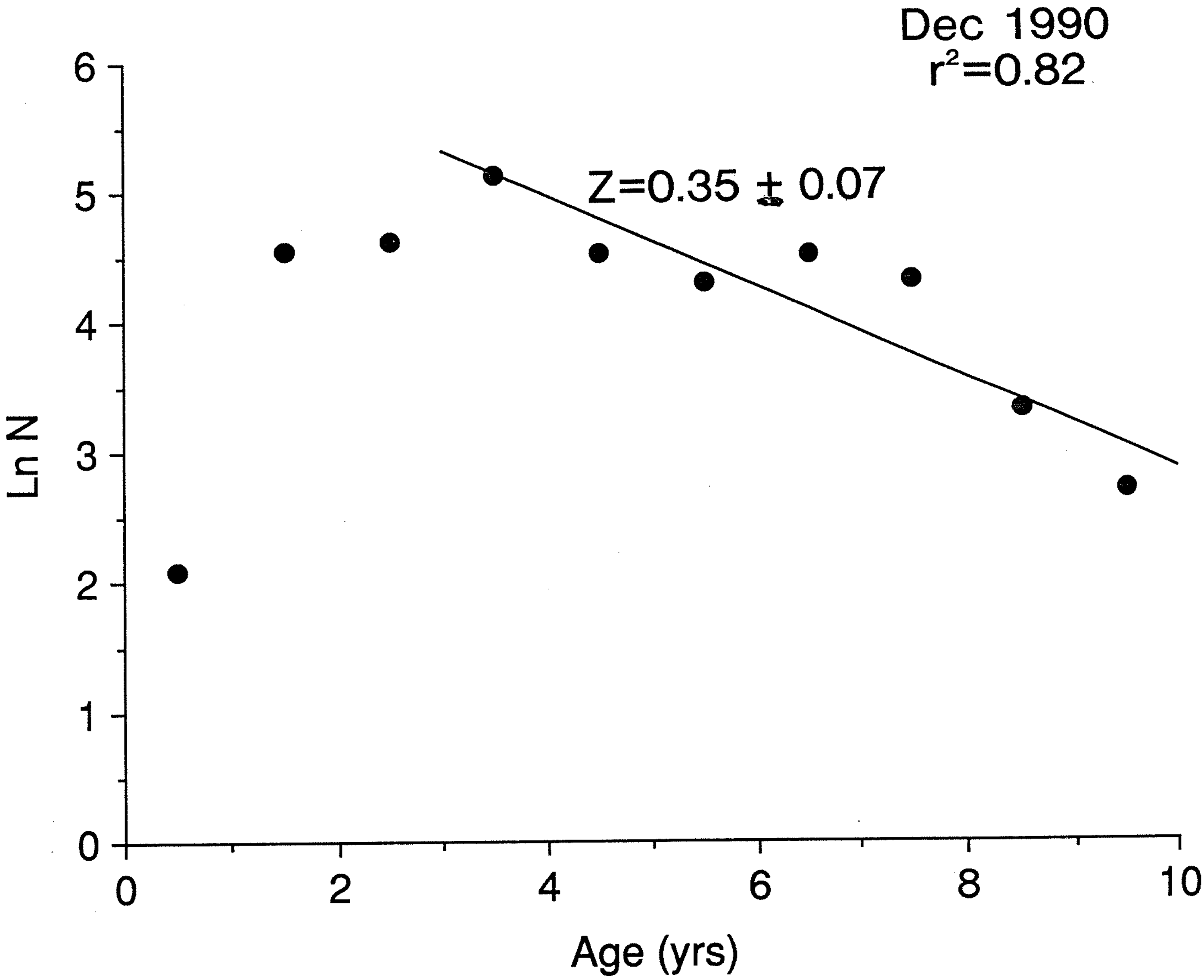
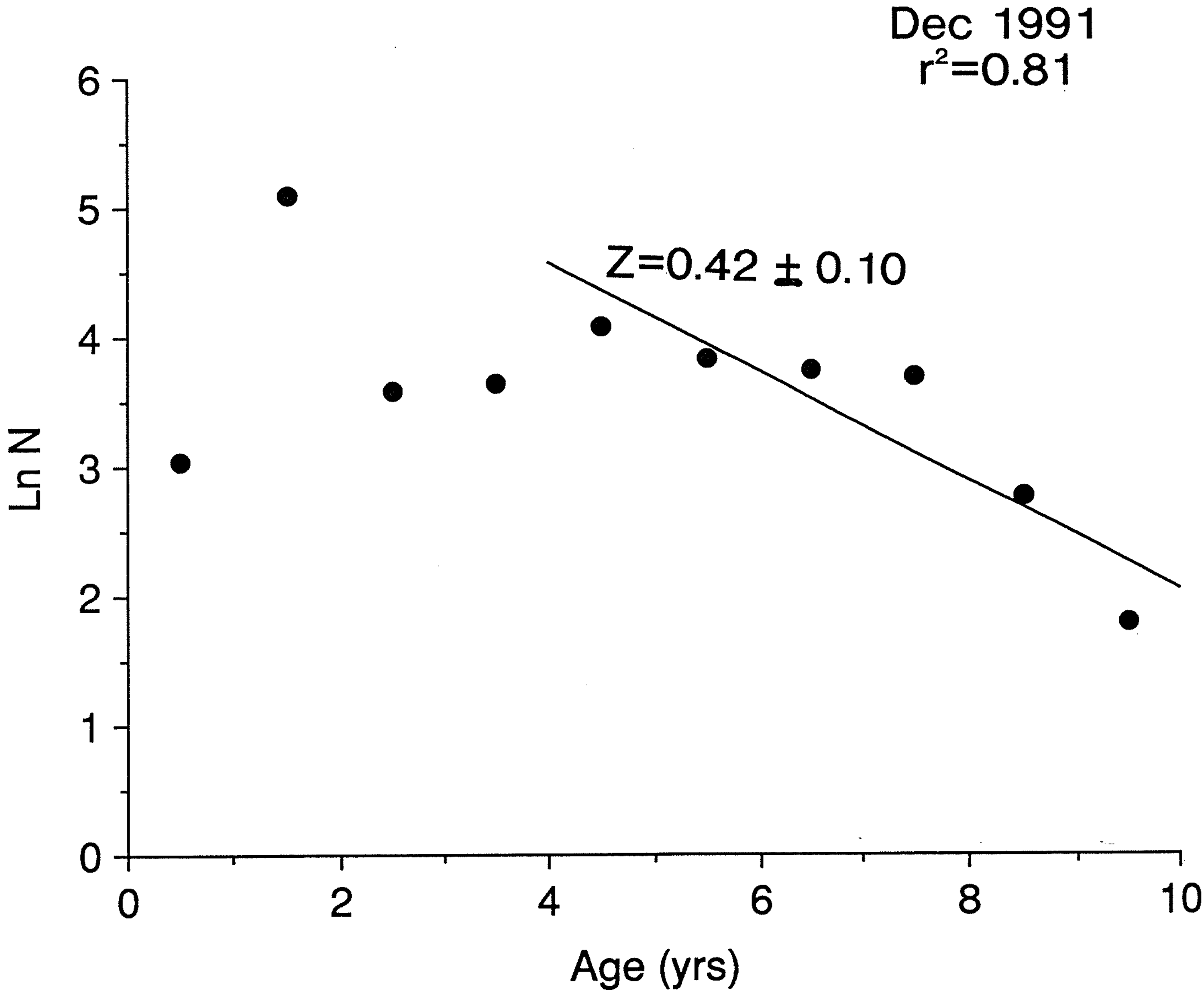

a
Dec 1990
N = 443
Age 7+
Age 6+
Age 5+
Age 4+
Age 3+
Age 2+
Age 1+
Age 0+
Frequency
0
10
20
30
40
50
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58
Length (cm)
b
Dec 1991
N = 294
Frequency
0
10
20
30
40
50
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58
Length (cm)

Fig. 11



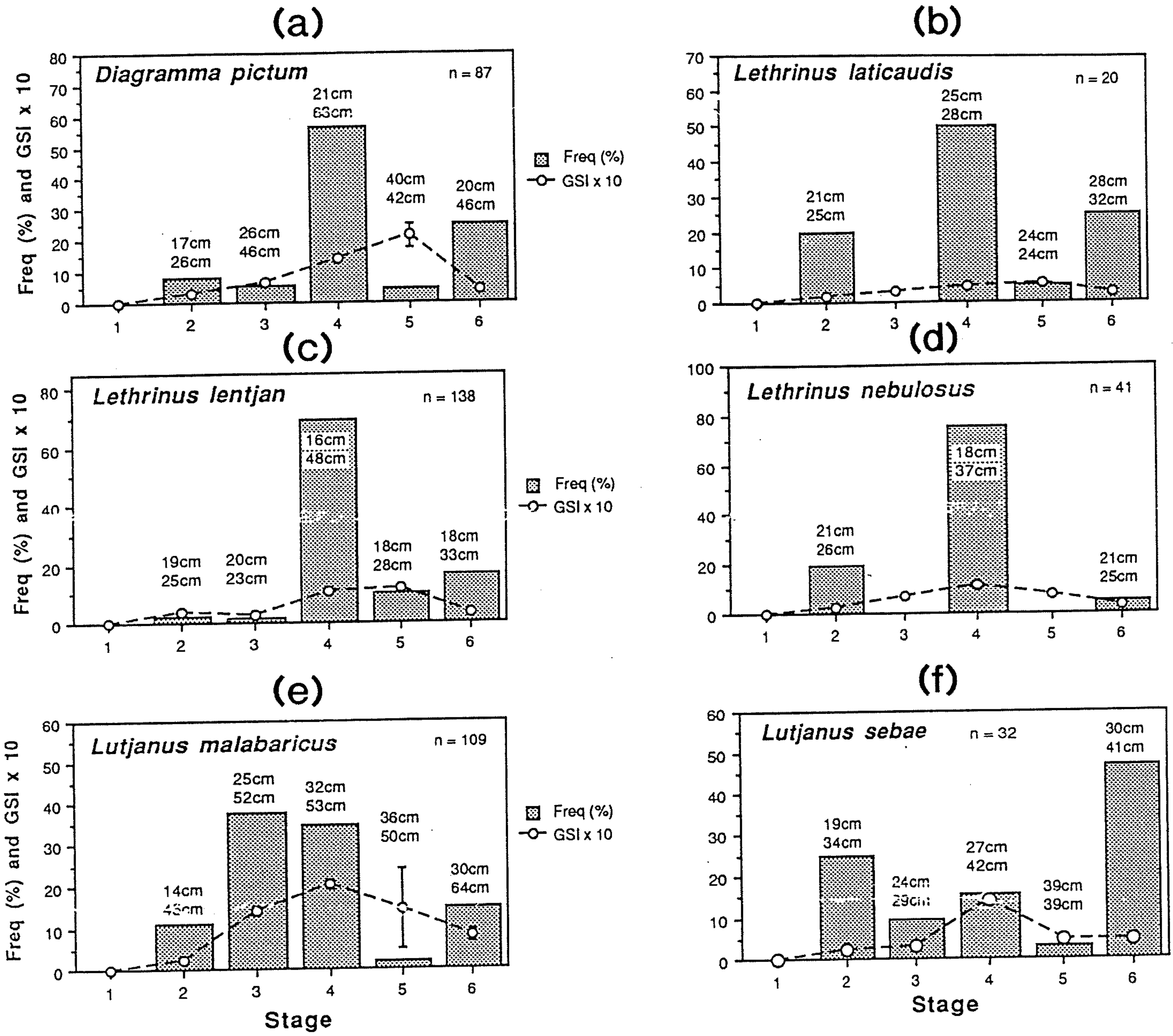
SC:LMAL_CAT.PLT 27-NOV-1992 10:46:05.00

Fig. 12



SC:LMAL_CAT.PLT 27-NOV-1992 10:58:00.32

Fig. 13


(a)
Diagramma pictum
n = 87
17cm
26cm
26cm
46cm
21cm
63cm
40cm
42cm
20cm
46cm
(b)
Lethrinus laticaudis
n = 20
21cm
25cm
25cm
28cm
24cm
24cm
28cm
32cm
(c)
Lethrinus lentjan
n = 138
19cm
25cm
20cm
23cm
16cm
48cm
18cm
28cm
18cm
33cm
(d)
Lethrinus nebulosus
n = 41
21cm
26cm
18cm
37cm
21cm
25cm
(e)
Lutjanus malabaricus
n = 109
14cm
43cm
25cm
52cm
32cm
53cm
36cm
50cm
30cm
64cm
(f)
Lutjanus sebae
n = 32
19cm
34cm
24cm
29cm
27cm
42cm
39cm
39cm
30cm
41cm
Freq (%) and GSI x 10
Freq (%)
GSI x 10
Stage

APPENDIX 1

Scientific publications arising wholly or partially from FIRDC Grant 90/29

Blaber, S.J.M., Brewer, D.T., A.N. Harris (1993). The distribution, biomasses and community structure of fishes of the Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. **44**: (in press)

Brewer, D.T., Blaber, S.J.M., Milton, D.A. and J.P. Salini (1993). Aspects of the biology of Caranx bucculentus (Teleostei: Carangidae) from the Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. **44**: (in press)

Harris, A.N., Blaber, S.J.M., Brewer, D.T. and D.A. Milton (1993). Aspects of the biology and factors affecting the distribution of commercial fishes in the Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. **44**: (in press)

Long, B.G. and I.R. Poiner (1993). Infaunal benthic community structure and function in the Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. **44**: (in press)

Long, B.G. and I.R. Poiner (in prep) Community structure of the epibenthic fauna of the Gulf of Carpentaria. (submitted to Aust. J. Mar. Freshw. Res.)

Salini, J.P., Blaber, S.J.M. and D.T. Brewer (1993). Diets of trawled predatory fish of the Gulf of Carpentaria with particular reference to prawn predation. Aust. J. Mar. Freshw. Res. **44**: (in press)

APPENDIX 2

Infaunal Benthic Community Structure and Function in the Gulf of Carpentaria, Northern Australia

B. G. Long and I.R. Poiner

CSIRO Marine Laboratories, P.O Box 120, Cleveland
Queensland 4163, Australia

ABSTRACT

The infaunal benthos (> 20 m) of the Gulf of Carpentaria was surveyed during November and December 1990. Over 680 taxa were collected with three replicate 0.1m^2 Smith-McIntyre grab from 105 stations. The Gulf benthos was highly structured with trends in abundance and species richness which were related to Gulf wide trends in sediment texture. Highest abundance (200 - 1 530 m^{-2}), wet weight biomass (x = 76 g.m^{-2}) and species density (x = 25.8 0.1 m^{-2}) occurred in the sands and muddy sands along the eastern and south-eastern margins of the Gulf. Abundance (33 - 200 m^{-2}), biomass (x = 30 g.m^{-2}) and species density (9.5 m^{-2}) was lowest in the muds and sandy muds in the central, west and north-west Gulf. Within-station species density was generally low (3.0 - 53.5 0.1m^{-2}) but the species richness of the Gulf was high. This was due to a large number (486) of rare (< 4 individuals) species. The Gulf infaunal abundance and biomass was similar to other tropical shelves but was lower than some temperate region continental shelves and upwelling areas. Species richness was also lower than in temperate areas of upwelling or high production.

Scavengers/carnivores and deposit feeders numerically dominated throughout the Gulf with these two feeding modes found in 85% of the infauna (43 and 42% respectively). Suspension feeding was less prevalent (13%) and very few herbivores were found (< 1%). There was a trend in the proportion of deposit and suspension feeders which was related to sediment texture. Suspension feeding was highest in the muddy sands of the east and south-east Gulf and lowest in the muds of the north-west. The proportion of deposit feeders was highest in muddy sediments and lowest in sandy sediments. Small (< 5 mm) surface deposit feeders numerically dominated within this feeding mode.

The 15 numerically dominant taxa accounting for over 37% of the infauna collected were comprised mainly of opportunistic, or second stage colonizing taxa. Most had Gulf wide distribution patterns but levels of abundance were correlated with sediment.

Ten station groups, identified from classification and ordination of the abundance data, were also related to sediment texture. The spatial overlap of most station groups, and overlap of principal co-ordinate scores from the ordination analysis indicated that the species assemblages in the Gulf did not form discrete communities, either spatially or in terms of species composition but that species were responding individually to factors associated with, or correlated with, sediment grain size.

The communities in the Gulf of Carpentaria appear to be regulated by physical factors of the environment which correlate with sediment grain size. These results are consistent with other workers on tropical benthos that these are resilient communities, dominanted by small, predominantly surface feeding, stress tolerant or opportunistic species, and are regulated and structured by environmental factors.

APPENDIX 3

Form B

RURAL INDUSTRY RESEARCH FUND GRANT
Statement of Receipts and Expenditure
(For the year ending 30 June 1992)

TG

RESEARCH TRUST FUND

		Grant	$
Trust Fund:	FIRDC	Salaries	83,200
Project Number:	91/29	Travel	–
Grantee:	CSIRO Division of Fisheries	Operating	5,000
Title of Project:	Determination of the biological parameters required for the rational management and exploitation of the fishes of the Gulf of Carpentaria.	Capital	– –
		Total Grant	88,200

	Expenditure									
	Salaries		Travel		Operating		Capital		Total	
	$	¢	$	¢	$	¢	$	¢	$	¢
A) Uncommitted (c/f 1 July)	–	–	–	–	–	–	–	–	–	–
B) Outstanding commitments (c/f 1 July)	–	–	–	–	–	–	–	–	–	–
C) Refunds of Grant	–	–	–	–	–	–	–	–	–	–
D) Cash Received from Trust Fund	83,200	00	–	–	5,000	00	–	–	88,200	00
E) Approved transfers (from Form C)	–	–	–	–	–	–	–	–	–	–
F) Cash available (A+B–C+D±E)	83,200	00	–	–	5,000	00	–	–	88,200	00
G) Expenditure	76,161	00	–	–	4,999	20	–	–	81,160	20
H) Outstanding commitments (30 June)	7,310	00	–	–	–	–	–	–	7,310	00
I) Total funds committed (G+H)	83,471	00	–	–	4,999	20	–	–	88,470	20
J) Uncommitted (30 June) (F–I)	(271	00)	–	–	0	80	–	–	(270	20)
K) Other income (Paid to Trust Fund)	–	–	–	–	–	–	–	–	–	–

Note: Row B should be the same as Row H from the previous year and Row A the same as Row J from the previous year.

Certificate of Accounting Officer

I hereby certify that this statement is correct.

(Signature)	C Williamson (Printed Name)	A/g Finance Manager (Position)	(002) 206 233 (Phone No.)