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SUMMARY OF THE FISHERY AND BIOLOGY OF THE JUMBO SQUID (*DOSIDICUS GIGAS*) IN THE GULF OF CALIFORNIA, MEXICO[1]

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Introduction

The Giant or Jumbo squid, *Dosidicus gigas*, is one of the most abundant of all cephalopod resources in western Mexican waters. A large fishery based on this species has developed in the last three years mainly in the Gulf of California. Existing knowledge about the biological characteristics and exploitation of this species is very limited. Thus an extensive research program to define the taxonomy, biological and ecological characteristics, stock size and exploitation effects was established in 1979. The preliminary results presented here are those generated by analyses of exploratory data as well as commercial statistics. A summary of the main findings together with some relevant information from the literature follows.

Identity

Dosidicus gigas is a member of the family Ommastrephidae placed in the sub-family Ommastrephinae. Diagnostic morphological characters are given by Wormuth (1976).

Distribution and Migration

Dosidicus is an oceanic squid with neritic components. It is found in the eastern Pacific from 36°N to 26°S and westward to 125°W.

Areas of high density exist from 0° to 18°S and from 16°N to 28°N, including the Gulf of California (Nesis, 1970; Suda, 1973; Sato, 1976; Wormuth, 1976). The population inhabiting Mexican waters migrates in and out of the Gulf of California most probably in response to feeding and spawning activities. Migration into the Gulf is initiated in January, reaching its northernmost position (29°N) by April. From May to August the stock is found mainly in the upper central section of the Gulf. Starting in July it extends towards the eastern side. Toward the end of August and into September the stock migrates back towards the entrance of the Gulf. At the entrance it separates into two components, one migrates south along the mainland coast and the second extends around the tip of Baja California Peninsula.

The species follows a diel vertical migration which is a common feature in ommastrephids (Clarke, 1966; Roper and Young, 1975).

The Fishery

Fishing for Jumbo squid in the Gulf of California started in 1974, with the operation of a small artisanal fleet working seasonally. Beginning in 1978 the off-season shrimp fleet entered the fishery. In 1979, large Japanese jigging boats commenced fishing. The increase in fleet size coupled with changes in national squid buying policies brought about an explosive growth of the order of 440% in total landings in 1980. Yearly production is given in Table 1.

The fleet has been divided into six categories depending on size of vessels and mode of opera-

[1] Summary of a paper to be published by FAO.

TABLE 1

Year	1974	1975	1976	1977	1978	1979	1980
Catch (metric tons)	14.0	43.4	147.0	300.0	2 000.0	5 000.0	22 000.0

tion, which have direct relation to trip lengths and type of product unloaded. In brief, category 1 comprises open boats, 6-8 m LOA; category 2, snapper boats, 16 m LOA; category 3, shrimp boats, 23-25 m LOA, icing the catch with 20-25 day trips; category 4 shrimp boats, same LOA as category 3, no preservation and daily trips; category 5, small Japanese jigging vessels, 35-40 m LOA; category 6, large Japanese jigging vessels, 48-52 m LOA.

Two types of jigs are commonly used: (a) Japanese type with two steel-hook crowns, 12 cm body size, 12 and 18 mm hook size, and (b) locally built jigs made out of aluminium tube, 30 cm in length and nail crowns as hooks. Japanese jigs are used in combination with automatic or manual jigging machines, as opposed to the local jigs which are used in a one line-one man fashion.

The efficiency of the fleet components was measured relative to the fishing power of the different categories. For this purpose an analysis of variance model derived from the catch equation was used (Robson, 1966). The information analyzed was catch per night operation, for each vessel category working in main squid fishing grounds. Results are shown in Table 2.

TABLE 2

Category	1	2	3	4	5	6
Fishing Power	1.0	1.5	1.5	6.5	11.1	28.0

Similarities between categories 2 and 3 are related to the same number of fishermen fishing with hand lines in boats of different sizes. Differences between categories 3 and 4 are due to differences in operational procedures.

Experiments were performed to evaluate jig efficiencies due to color preferences. Relative jig efficiencies are arranged in descending order: transparent (1.0); red (0.9); pink (0.8); green and silver (0.5). The superior efficiency of transparent jigs is due to bubbles created by holes in the soft plastic body of these jigs. Efficiencies in the other jigs are due solely to colors.

A selectivity study showed that small individuals are caught equally well by both small and large jigs. Large individuals, though still caught with small jigs, are caught in fewer numbers because the smaller hooks do not hold the weight of larger squids (Figure 1). However, in the 12 to 47 cm ML range capture rates with small Japanese jigs and large locally built jigs are the same. Jig selectivity for Jumbo squid is thus a function of the ability of the hook size to retain weight rather than a function associated with jig body size.

Food and Feeding

Most authors agree that *D. gigas* is an active predator at all stages of its life, attacking almost any prey available. The diet is size dependent (Fitch, 1968). Qualitiative analyses of stomach contents show that components vary in accordance with prey species available in different areas (Fitch, 1968; Nesis, 1970; Sato 1976). Jumbo squid in the Gulf of California feed mainly on sardines (*Sardinops sagax caerulea*). In areas of intensive fishing it has been shown conclusively that Jumbo squid are cannibalistic especially on those individuals that have been badly wounded after escaping jigs. The large percentage of empty stomachs observed is due to a very high digestion rate rather than a lack of prey species, which are abundant in the area.

Sexual Maturity

Very little is known about the reproductive cycle of *D. gigas*. Off Chile and Peru, size of first maturity is 20-25 cm ML for males and 36-37 cm ML for females (Nesis, 1970). In the Gulf of California size at first maturity for males occurs when individuals are between 18 to 25 cm ML. Females first mature when they are 35 to 40 cm ML. In males the number and size of spermatophores increase as a function of age and size.

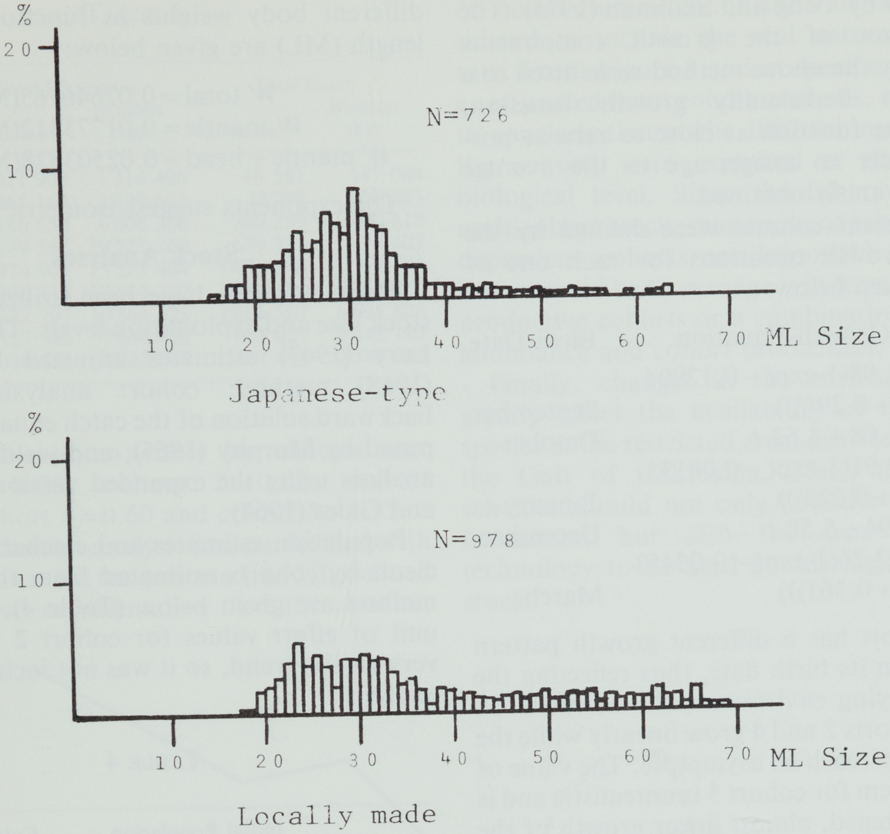


Figure 1. Size frequency distribution for squids caught with Japanese type jigs and large locally made jigs.

Studies of maturity in the Gulf of California show several spawning periods. The most important occurs during December-January, recruiting to the fishery during March and April. A second spawning period occurs in May and June that will recruit in September. A third peak is observed in September whose progeny will recruit in January and February. Mature females are found during most of the year. Three major spawning areas have been defined, one in the eastern central and another in the western central part of the Gulf. A third area is found off the Gulf at the edge of the continental shelf west of the Baja California Peninsula.

The reproductive cycle is not easily defined and appears to be heavily dependent on oceanographic conditions of the area.

Age and Growth

Aging of cephalopods is difficult since few hard parts are found which show annual or other time-related signals. Age and growth estimates for *D. gigas*, given by Nesis (1970) are 20-33 cm for one year old squid, 34-45 cm for two year old and more than 46 cm for three and four year old individuals. Nesis calculated monthly growth rates as 2-2.5 cm during the first year of age and 1-1.2 cm for the second year.

Growth rates for other ommastrephids have been given by Fridriksson (1943), Murata and Ishii (1977), and Araya (this volume).

Maximum size for *D. gigas* varies according to latitude and hemisphere (Berry, 1912; Clarke, 1966; Garcia-Tello, 1965; Nesis, 1970; Phillips, 1961; Wormuth, 1976).

Age and growth studies for the species in the Gulf were conducted with information on monthly mantle length frequency distributions and analysis of the polymodal distributions was as proposed by Yong and Skillman (1975). The average sizes of the growth components separated by the above method were fitted to a simple von Bertalaniffy growth function, adjusting the function as close to zero as possible in order to assign age to the average lengths previously obtained.

Five different cohorts were defined by the analysis. Growth equations for each one of them are given below:

Cohort	Growth Equation	Birth Date
1	$L_t = 91.98(1\text{-}\exp(-0.12904(t+0.291)))$	September
2	$L_t = 11.08 + 4.62\ t$	October
3	$L_t = 99.91(1\text{-}\exp(-0.08133(t+0.229)))$	January
4	$L_t = 6.94 + 5.58\ t$	December
5	$L_t = 152.26(1\text{-}\exp(-0.05453(t+0.361)))$	March

Each cohort has a different growth pattern depending on its birth date, thus reflecting the effect of varying environmental conditions on growth. Cohorts 2 and 4 grow linearly while the others tend to reach an asymptote. The value of $L_\infty = 152.26$ cm for cohort 5 is unrealistic and is due to a flattened, almost linear growth of the cohort. As such the model in this case is valid only for the range of observed lengths (<50 cm ML). Maximum observed mantle length for all cohorts was 75 cm. In this way, L_∞ values for cohorts 1 and 3 are considered reasonable.

Monthly growth rates from the above functions and for each cohort are presented in Table 3.

TABLE 3

Cohort Age (Months)	1	2	3	4	5
	Growth Rates (cm/mo)				
1- 4	8.33	4.62	6.52	5.58	7.11
5- 7	5.29	4.62	4.90	5.58	5.87
8-10	3.59	4.62	3.84	5.58	4.99

The above growth rates define *D. gigas* as a very fast growing animal as compared with other oceanic ommastrephids. From these same growth patterns it is evident that this species does not live more than 18-20 months.

Length-weight relationships obtained for different body weights as function of mantle length (ML) are given below:

$$W\ \text{total} = 0.02646165(\text{ML})^{2.989379}$$
$$W\ \text{mantle} = 0.01775312(\text{ML})^{2.940475}$$
$$W\ \text{mantle} + \text{head} = 0.02503828(\text{ML})^{2.937908}$$

The exponents suggest isometric growth.

Stock Analyses

Three methods have been utilized to assess stock size and exploitation levels. These are: De Lury (1947) estimates adjusted by Braaten (1968) method; cohort analysis using a backward solution of the catch equation as proposed by Murphy (1965); and yield per recruit analysis using the expanded version of Paulik and Gales (1964).

Population estimates and catchability coefficients by cohorts estimated from the De Lury method are given below (Table 4). Catch per unit of effort values for cohort 2 followed a very erratic trend, so it was not included in the analysis.

TABLE 4

Cohort	Initial Population (No) In Numbers	Catchability Coefficient (q)
1	954 297	0.00008
3	2 359 185	0.00010
4	3 707 255	0.00011
5	1 121 339	0.00023

A *t*-test showed no significant differences at the 95% confidence level between *q*-values, implying that each unit of effort was catching the same fraction from each of the cohorts.

Population estimates for all cohorts combined, estimated from cohort analysis are shown in Table 5.

Maximum biomass occurs during May and June while maximum fishing effort which is dephased one month from the optimum occurs during June and July (Figure 2). Likewise, months of maximum effort correspond to population sizes which represent 45.6% and 24.3% of the initial population, whereas during May the population available to the fishery represents 72.6% of the initial population.

Fishing mortality rates (F) averaged over the

TABLE 5

	Total Population		Total Catch	
Month	In Numbers	Biomass (kg)	In Numbers	Biomass (kg)
Jan	9'611 908	1'314 406	48 561	147 044
Feb	8'861 166	3'320 603	73'793	104 233
Mar	8'146 654	6'608 266	260 259	340 618
Apr	8'389 552	10'523 260	679 211	974 407
May	6'974 903	13'573 404	1'475 194	1'902 177
Jun	4'386 115	12'544 727	3'170 190	5'559 013
Jul	2'337 707	10'563 121	1'696 567	6'895 828
Aug	1'327 342	7'804 480	685 027	3'448 183
Sep	1'038 585	7'222 269	487 495	2'349 602

period of maximum effort by cohorts are: cohort 1 = 0.28; cohort 2 = 0.22; cohort 3 = 0.39; cohort 4 = 0.60 and cohort 5 = 1.35.

Yield per recruit analysis was performed with growth parameters for cohorts 1 and 3, defined as the most representative for the species. M-values used were 0.05 and 0.08, a range considered to include the real natural mortality rate. From Figure 3 and at specific values of F as estimated from cohort analyses, it is possible to conclude that at the 1980 fishing effort level the cohorts were exploited at the optimum biological level. Since the fishery acts on a multicohort stock, management schemes by independent cohorts are impossible. An alternative could be to manage it in terms of the less productive cohorts or a combination of cohort abundance and cohort production.

Finally, changes in the environment may greatly affect the availability of this oceanic species in the restricted areal distribution within the Gulf of California. Thus, management schemes should not only consider quantity of investment but also the type of fishing technology to be used in this highly dynamic stock.

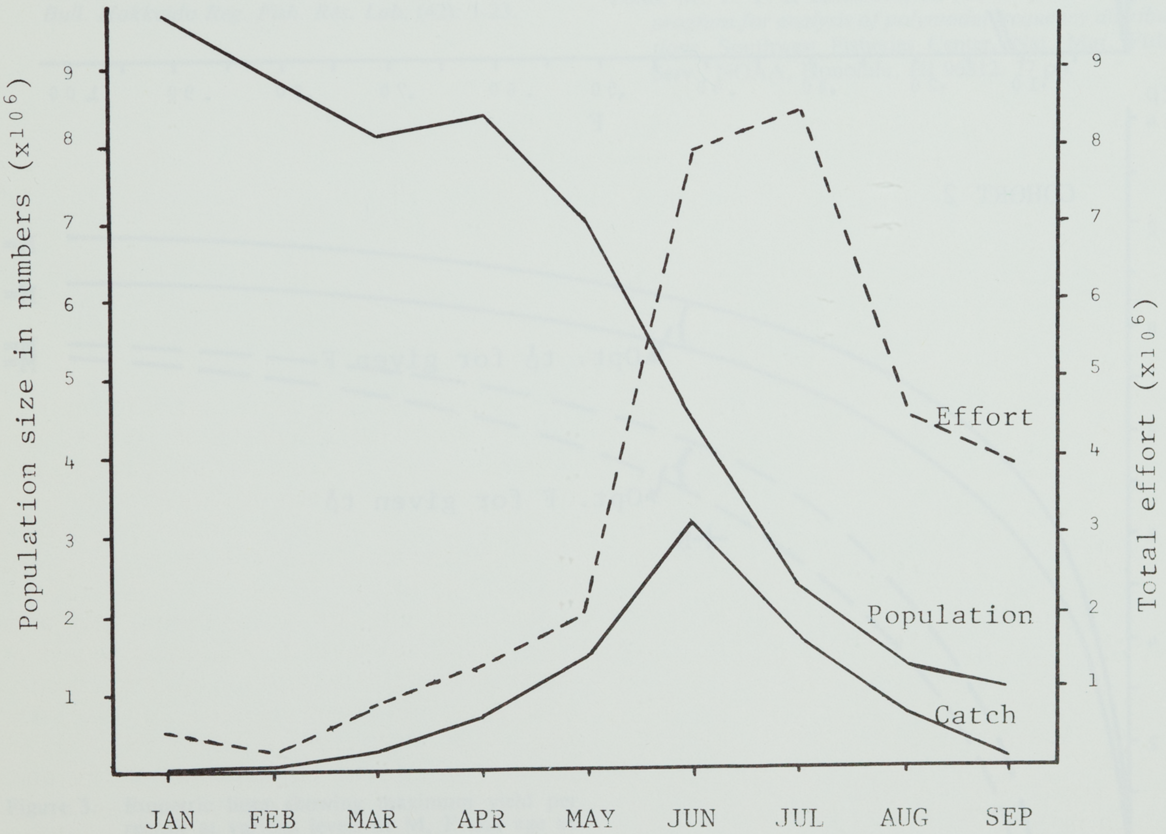
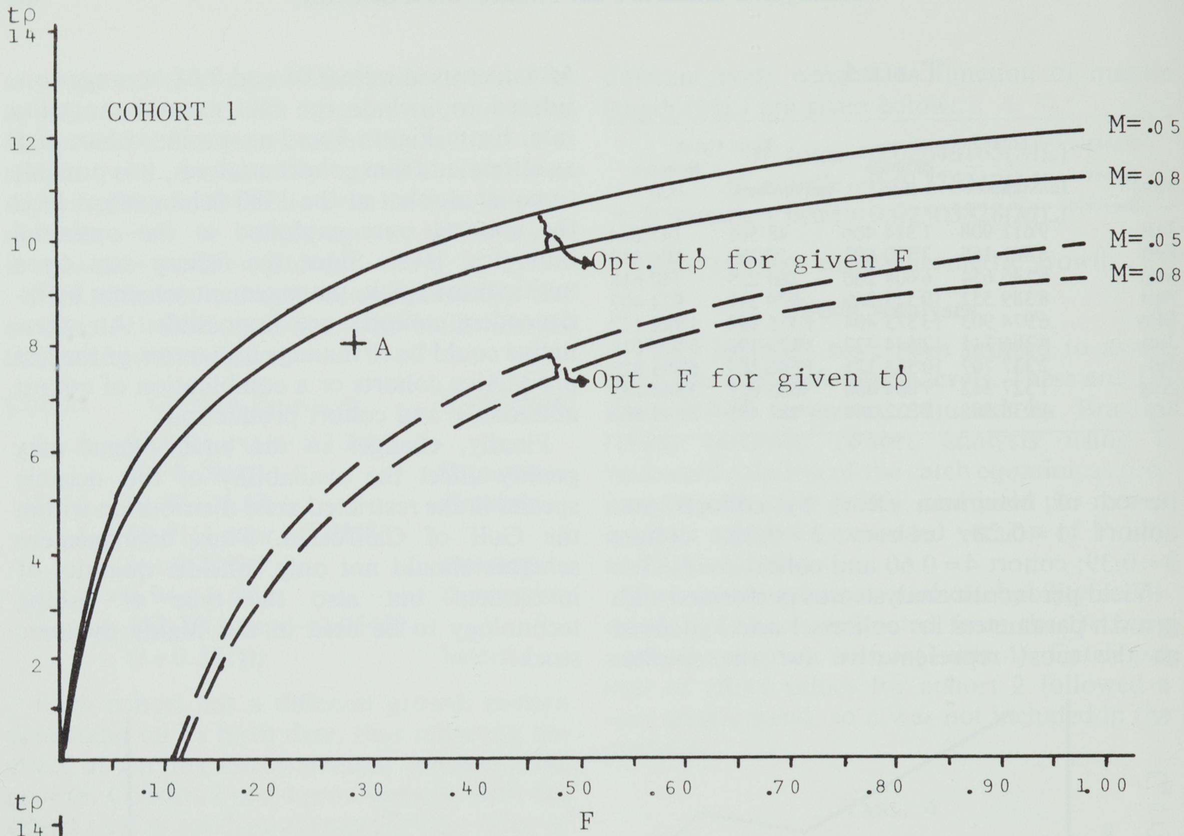


Figure 2. Estimated population size, catch and effort from January to September 1980.


tρ
14
12
10
8
6
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COHORT 1
M=.05
M=.08
M=.05
M=.08
Opt. tρ' for given F
Opt. F for given tρ'
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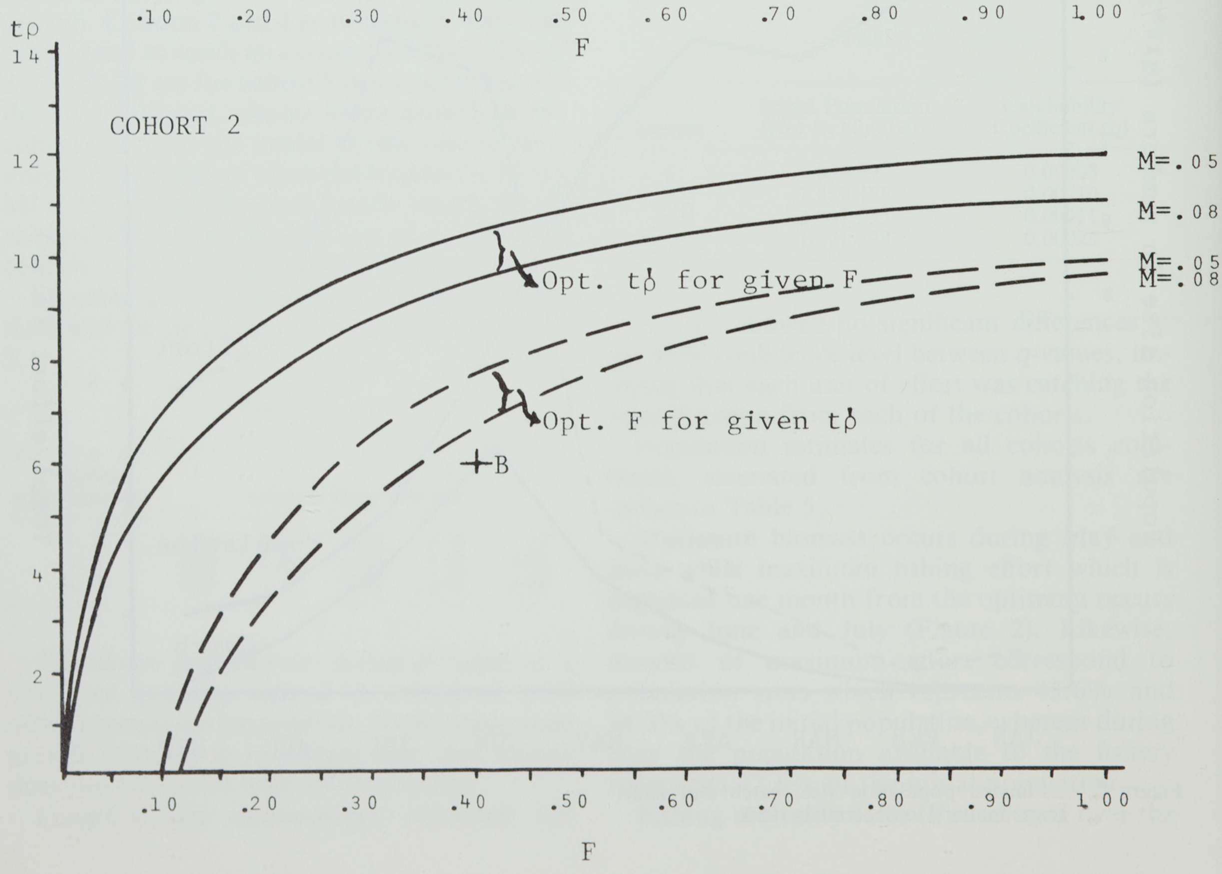
tρ
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COHORT 2
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Opt. tρ' for given F
Opt. F for given tρ'
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Figure 3. Eumetric lines showing maximum yield per recruit at various levels of M, F and age of recruitment, t'_ρ, for cohorts 1 and 3. Points A and B show actual position of cohort exploitation.