Sustainability of Fisheries for Deep-water Cartilaginous Fishes

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Introduction

The global crisis of shallow fisheries resulted in a new interest for fishing in deep waters, increasing the impact of fishing activities on deep-water ecosystems.

We analyzed trends in landings of deep-sea cartilaginous fishes since 1950 to 2002, and estimated productivity of deep-sea cartilaginous fishes for which information on life history exists. Finally, we assessed sustainability of current fishing pressures taking the factor of landing increase as a rough estimate of the increase in fishing mortality.

Stage-based matrix models were developed to estimate the rate of increase of four deep-sea sharks (*Centrophorus squamosus, C. granulosus, Centroscymnus coelolepis* and *Deania calcea*), and one chimaera (*Chimaera monstrosa*).

Material and Methods

The stage based models were developed for each species in order to obtain an estimate of the rate of population increase (r). According to the life history of every species the models' stages and their duration differed among species (Fig. 1). For every stage, the probability of surviving and growing into another stage, G, and the probability of surviving and remaining in a stage, P, were calculated as:

$$G_i = p_i^{d_j} (1 - p_i) / (1 - p_i^{d_j}) \quad \text{and} \quad P_i = ((1 - p_i^{d_j-1})/(1 - p_i^{d_j}))\, p_i$$

where d_j is stage duration in yr and p_i is the stage-specific survivorship values calculated from Jensen's estimates of mortality as M = 1.65/age at maturity. In all cases, we considered the mortality of neonates as double of the juveniles; the other stages were considered to have the same mortality value.

Elasticity analyses were performed in order to identified the most sensitive stages.

The impact of fishing on each chondrichthyan species was assessed by multiplying mortality by a factor obtained by dividing the maximum landing by the minimum landing larger than zero. This factor was applied to the stages exposed to fishing: subadults and adults stages for all species, excepting *C. granulosus* in which fishing was applied to juveniles and adults.

Life history parameters used in this study are presented in Table 1.

Table 1. Life history parameters of the studied species

	Age to maturity (years)	Life span (years)	Litter size	Reproductive periodicity (years)	Gestation length (years)	Source
Chimaera monstrosa	11.71	28.88	22	1	1	1,2,3
Centrophorus squamosus	44	70	8	1	1.5	4,5,6
Centroscymnus coelolepis	5.52	15.30	6 8.09	2	1	4,7,8,9
Centrophorus granulosus	12.2	25	1	1	2.5	10
Deania calcea	25	35	13	4	1.83	6,11

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Results

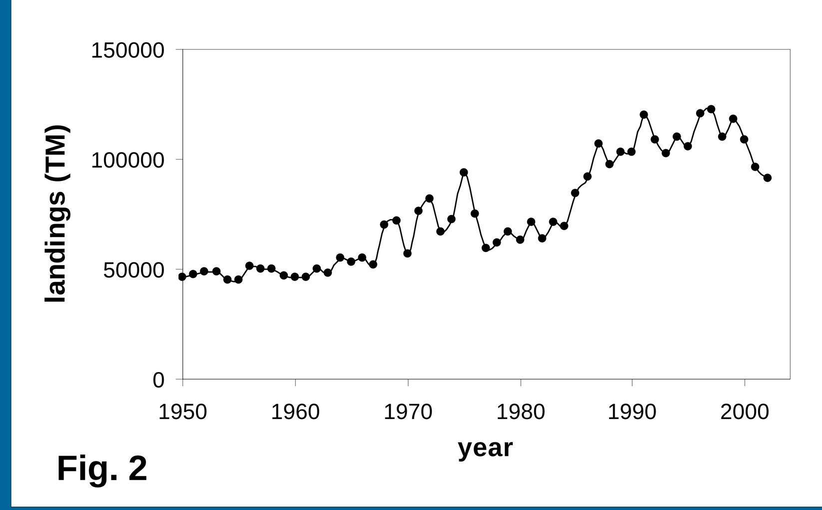


Fig. 2

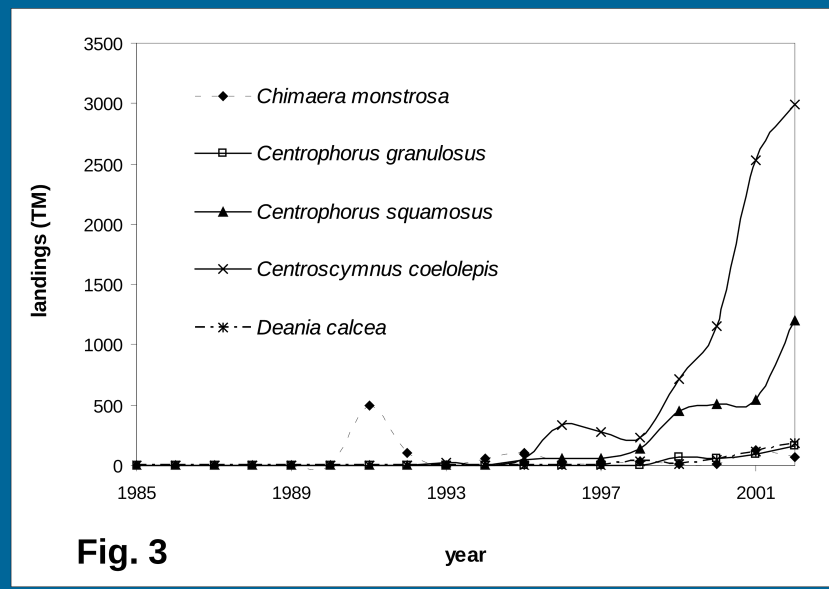


Fig. 3

✓ Reports of landings of deep sea cartilaginous fishes are as early as 1950 and there is an increasing trend since that year (Fig. 2). However, species are often lumped into broad categories (e.g. Rajiformes, Squalidae).

✓ Since 1990, landings reports became more accurate reporting some species individually. Species specific landings increased by a factor of 53-1588, depending on the species (Fig. 3).

✓ In general, without any exploitation all species studied have low productivity (r ranging from 0 to 0.05), except *C. coelolepis* and *C. monstrosa*, which have moderate productivity (r = 0.17) (Table 2).

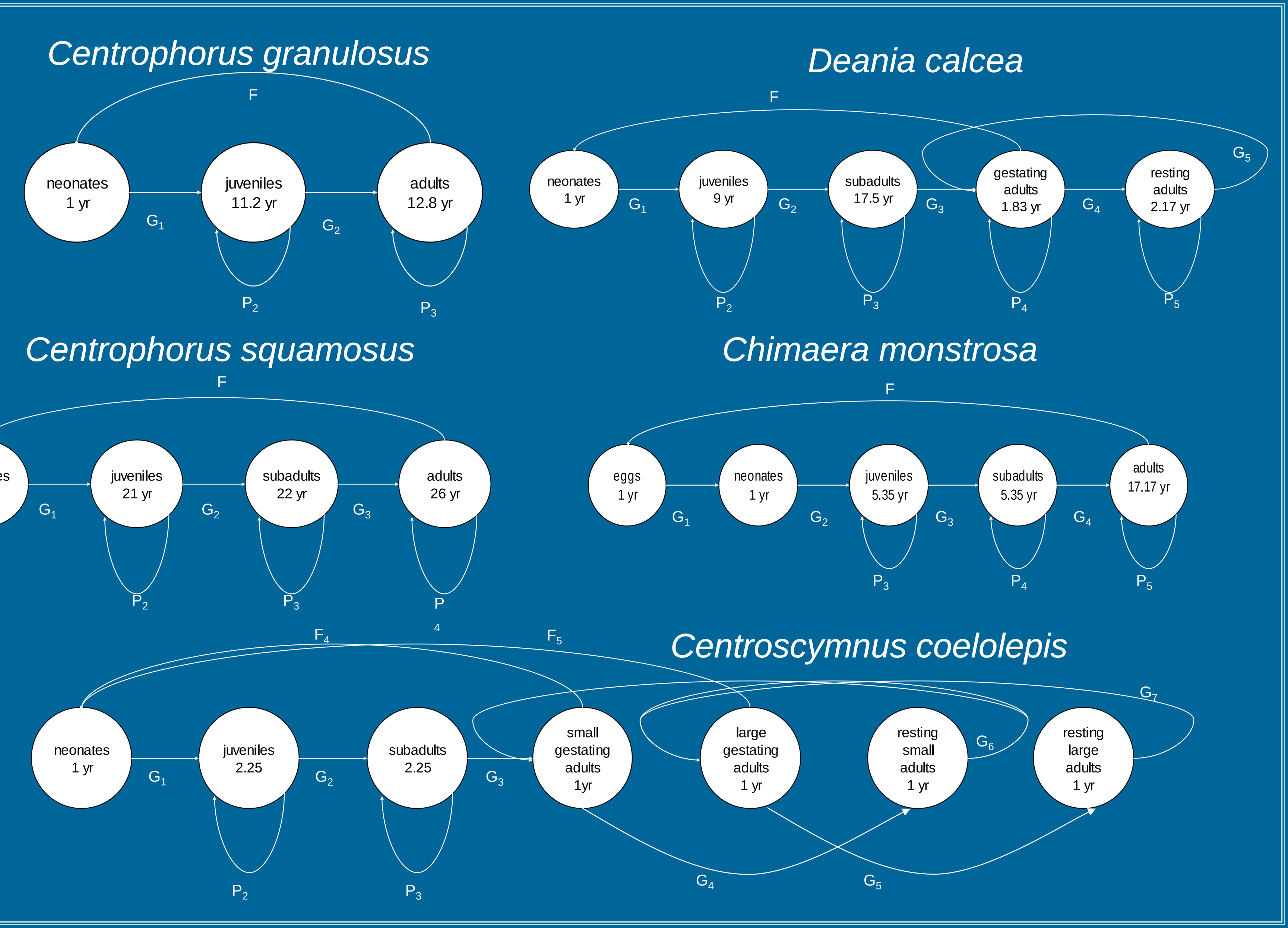
✓When mortality is changed by the same factor as landings increased, all species studied showed a negative rate of population increase. From the most to the less impacted, species are ordered as follow: *C. granulosus, C. coelolepis, C. monstrosa, D. calcea,* and *C. squamosus* (Table 2).

Table 2. Population rates of increase of the five analyzed species of deep sea chondrichthyans.

	r without fishery	r with fishery
Centrophorus granulosus	-0.08	-7.26
Centroscymnus coelolepis	0.17	-0.75
Chimaera monstrosa	0.17	-0.28
Deania calcea	0.05	-0.15
Centrophorus squamosus	0.04	-0.07

✓ Elasticity analyses showed that the population dynamics of *C. squamosus*, *D. calcea*, and *C. monstrosa* is more sensitive to changes in the parameters of the juvenile stages and *C. coelolepis* and *C. granulosus* are more sensitive to changes in the adult stages (Fig. 4). This is expectable given the lower age at maturity of the latter two species.

Fig. 1



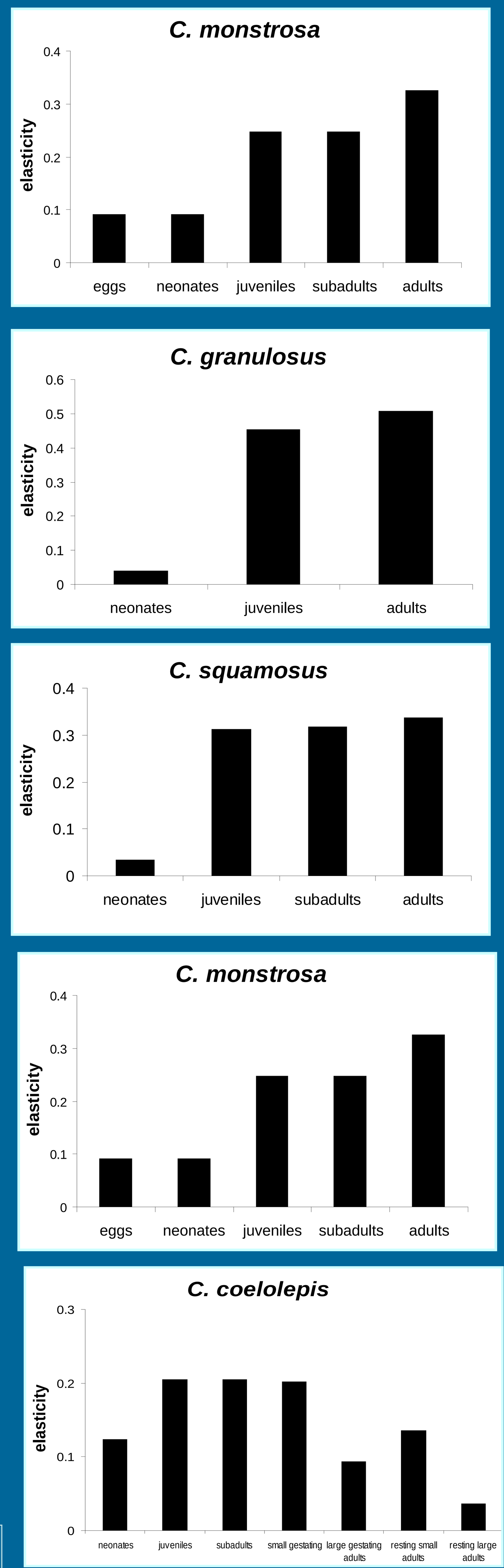


Fig. 4

Conclusion

Given the low values of r of the deep water cartilaginous fishes studied here, the sustainability of fisheries based on these species is possible with very low fishing mortalities.

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