Atrophic model of the Arabian Sea Ecosystem off Kamataka and simulation of fishery yields for its multigear marine fisheries


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"The oceans, unlike forests still look like the oceans after we have removed the contents, and even scientists are susceptible to being seduced to ignore phenomena that are out of sight"

Carlton, 1998

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Foreword

Marine living resources by virtue of their varied life history patterns, diverse growth and mortality rates are well known for dynamism. More importantly, all organisms that live in the sea predate upon other organisms and are also themselves predated upon by others. Thus this complex inter-relationships form a network or web-like links which are the foundation of trophic ecology. In recent times fishery scientists have come to recognize that management of marine fishery resources on a unit species/stock basis has little practical value in the multi-species context, particularly in the light of the inter-relationships mentioned before. Thus trophic modelling tools, such as ECOPATH, are being increasingly used to arrive at meaningful management plans and options for multi-species marine fisheries throughout the world. These models are an integral part of the much touted Ecosystem Based Fisheries Management (EBFM) approach which espouses that exploitation of various resource species should leave the ecosystems with their biodiversity and structural integrity intact, thus allowing for future services.

Apart from a very preliminary trophic model of the southwest coast of India made during the nineteen nineties, the present model of the Arabian Sea off Karnataka is the first comprehensive and detailed attempt to model an Indian marine ecosystem. The authors were able to build an inclusive trophic model with a reasonably high pedigree. Furthermore, they have gone on to simulate changes in biomass of different resources and yields of different fishing fleets of Karnataka consequent to increasing effort which will serve as a policy guide for the marine fisheries planners and managers in Karnataka State.

More than anything, the Karnataka Model presented in this publication, is a frontrunner and a guide to the future management of marine fisheries in India using the EBFM approach. The CMFRI has, based on the success of this model, reoriented its fishery biology data collection to cater to the needs of trophic modelling and is now embarking to build trophic models for other major marine ecosystems of India. I congratulate the authors Dr. K. Sunil Mohamed, Dr. P.U. Zacharia, Dr. C. Muthiah, Dr. K.P. Abdurahiman and Mr. Harish Nayak for the excellent work carried out and for consolidating the results in the form of this publication. I am sure that this bulletin will serve to inspire other fishery researchers in India to explore the complex world of trophic modelling and new-age fisheries management.

N.G.K. Pillai
Director

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Abstract

The concept of Ecosystem Based Fisheries Management (EBFM) has been adopted by many countries as proposed in the 2001 Reykjavik Declaration concerning marine ecosystem utilization and management. Under a project funded by the ICAR AP Cess Fund, the construction of a trophic model of the Arabian Sea ecosystem off Karnataka using the ECOPATH with ECOSIM (EwE) software was carried out. ECOPATH is a trophic accounting model that is a practical way of studying the trophic interactions of all species in an ecosystem by incorporating the energy flows between trophic levels and interactions among trophic components. ECOSIM calculates corresponding changes in biomass of each component when the fishing mortality of any particular group is altered. Using equilibrium simulations, where equilibrium biomass is plotted over a range of fishing effort (F values), ECOSIM provides the facility to predict the potential equilibrium yield for the fished group.

The project was also able to generate growth, mortality, biological, population and ECOPATH input parameters for 55 commercially important species which are presented as '*Species Life History Sheets*'. Besides by extensive stomach sampling (9786 fishes and shellfishes) of 56 species a comprehensive database on diets was made and presented as diet tables.

The Karnataka model encompassed an area of 27,000 km^2 and had 24 functional ecological groups. Estimates were made of the biomass, production/biomass ratios, consumption/biomass rates, and diet compositions for each functional group. The total system throughout represents the size of the entire system in terms of flow and was estimated as 11,522 t/km^2/year, which is comparatively high, but is consistent with tropical marine ecosystems with high turnover. The Karnataka model had a mean trophic level of 3.04. Gross efficiency of the fishery was estimated as 0.0016 (higher than the global average) indicating a fishery harvesting fishes low in the food chain. Based on the gross efficiency value of the ecosystem it can be classified as an ecosystem, which is in the process of achieving full maturity. Fully mature ecosystems have web like connections and are less susceptible to perturbations.

The Arabian Sea ecosystem of Karnataka had a system omnivory index of 0.299 indicating the diverse nature of feeding interactions between trophic levels. The estimates of net system production and total primary production by total biomass ratio also substantiated the fact that the ecosystem is immature. Trophic pyramids representing the distribution of biomass and energy flow indicate that the transfer efficiency from primary producers was estimated as 14.3% and from detritus 9.1%.

A simulation exercise using ECOSIM with a 17% increase in effort every year for 10 years indicated the changes in the biomass and yield of different components of the ecosystem for different fleets such as multi-day trawl, single-day trawl, purse-seine, hook and line, gillnet and artisanal fleets. The results show that increase in effort does not show proportional increase in total catch and value of the fishery indicating that effort increase is not recommended for these fleets along Karnataka coast. The present ecological model constructed and the simulations made are a preliminary exercise and with the availability of better information and more vigorous data, the model can be improved so as to reflect the reality in a better fashion.

1. Introduction

Ecosystem Based Fisheries Management

Fish populations are an integral part of marine ecosystems. Historically, fish population dynamics have been studied as single species, for example as mackerel, shrimp or sardine, and almost always in isolation from the system in which they exist. In recent years, however, there has been growing awareness that traditional approaches to managing fisheries are incomplete and partially unsuccessful. Sustainable use of living marine resources must consider both the impacts of the ecosystem on the living marine resources, and the impacts of fishery on the ecosystem. This holistic approach to fisheries management has been termed as '*ecosystem based fisheries management*'. 'The Principles of Ecosystem-Based Fisheries Management are: 1. Maintaining the natural structure and function of ecosystems, including the biodiversity and productivity of natural systems and identified important species, is the focus for management. 2. Human use and values of ecosystems are central to establishing objectives for use and management of natural resources. 3. Ecosystems are dynamic; their attributes and boundaries are constantly changing and consequently, interactions with human uses also are dynamic. 4. Natural resources are best managed within a management system that is based on a shared vision and a set of objectives developed amongst stakeholders. 5. Successful management is adaptive and based on scientific knowledge, continual learning and embedded monitoring processes.'

A lot of attention has recently been directed at assessing the impacts of fisheries on whole marine ecosystems (ICES, 1998, 2000; Frid et al., 1999b; Hall, 1999a, b). This has in part been driven by the need to ensure conservation of biological diversity and sustainable use of the biosphere, key provisions of the convention agreed at the UN Rio summit (Tasker et al., 2000). The utilization of sound ecological models as a tool in the exploration and evaluation of ecosystem health and state has been encouraged and endorsed by the leading bodies in ecosystem-based fisheries research and management (NRC, 1999; ICES, 2000). The potential of the available dynamic ecosystem models to make measurable and meaningful predictions about the effects of fishing on ecosystems has not however been fully assessed.

ECOLOGICAL FACTORS

Harvesting alters ecosystem structure in ways that are only beginning to be understood. It is argued that long-term heavy commercial harvesting is likely to shift the ecosystem to high-turnover species with low trophic levels (Pitcher and Pauly, 1998). The biological mechanism underlying species shifts is that the relatively large, long-lived fishes which have low mortality rates are more strongly affected by a given fishing mortality rate than are smaller fishes which are part of the same community. A second shift-inducing biological mechanism is habitat degradation caused by various fishing gears especially bottom trawls. Here, the effect is through destruction of bottom structure, depriving benthic fishes of habitats and prey.

Thirdly, the above and the fishery-induced reduction of predatory pressure by benthic fish, may then lead to an increase of small pelagic fish and squids, which becomes available for exploitation. This may mask the decline in catches of the demersal groups. In the Gulf of Thailand, in Hong Kong Bay and other areas of the South China Sea, extremely heavy trawl pressure has resulted in a shift from valuable demersal table fish such as croakers, groupers and snappers to a fishery dominated by small pelagics used for animal feed and invertebrates such as jellyfish and squids.

These mechanisms almost often lead, through a positive feedback loop, to a fourth biological mechanism: harvesting small pelagic fish species at lower trophic levels reduces the availability of food for higher trophic levels, which then decline further, releasing more prey for capture by a fishery that finds its targets even lower down the food web, a process now occurring throughout the world (Pitcher and Pauly, 1998). Some examples of such documented species shifts in exploited multispecies fish communities are shown in Table-1.

It has also been observed that fishes evolve or change their life histories in response to selective fishing mortality, for e.g., halving of the size of mature Chinook salmon. In this semelparous species, early maturity means less time at risk of being caught and therefore, higher fitness. This species has been intensively managed for over 80 years using the best that single species quantitative science can offer, and yet Chinook salmon are on the decline.

SOCIO-ECONOMIC FACTORS

One of the main socio-economic mechanisms, which contribute to species shift, is increasing prices, both for traditional high-value species and for trash species. Such price increases are effective in masking the economic consequences of fishing at lower trophic levels.

SINGLE SPECIES ASSESSMENTS

The tools developed for single species population dynamics are an essential part of any new methodology. Detailed information on growth, mortality and recruitment schedules

Table 1: Examples of documented shifts towards smaller, high-turnover species in exploited multispecies communities (modified from Pitcher and Pauly, 1998).

Fishing grounds/ Stocks (period)	Documented species shift
Gulf of Thailand Demersal stocks (1960-1980)	Overall biomass reduced by 90%; residual biomass dominated by trash fish
Philippine shelf Small pelagics (1950-1980)	Gradual replacement of sardine-like fishes by anchovies
Carigara Bay, Philippines All fish (1970-1990)	Fish replaced by jellyfish, now an export item
Black Sea	Small pelagics and jellyfish replace large table fish
North Sea	Halibut and small sharks extinct; cod and haddock threatened; demersal omnivores and small pelagics favoured
Humboldt Current, Chile	Large hake depleted, small pelagics favoured
North Pacific	First marine mammal depletions, followed by huge trawl fisheries: Pollock favoured
South China Sea, Hong Kong	Croakers and groupers almost extinct; small pelagics bulk of fishery

and their associated errors and uncertainties are essential for the implementation of the ecosystem approach advocated in the Rio summit.

When considering the management of single components of the ecosystem, such as the target fish stocks, it is possible to set target and limit reference points for particular measurable properties of the species. For example, the implementation of precautionary fisheries management in the North Atlantic has progressed through the setting of reference points for various measures of the status of the exploited species, e.g. the spawning stock biomass (SSB). Two types of reference point are considered - a limit reference point and a target reference point (Fig.1). Management measures are aimed at achieving the target reference point in the medium term and ensuring that the limit reference point is never exceeded.

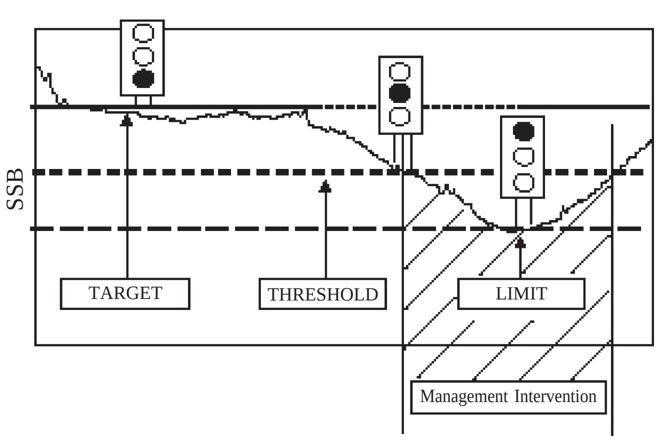


Fig. 1. Illustration of target, threshold and limit reference points with regard to spawning stock biomass (from Hall and Mainprize, 2004)

In theory, it should be possible to apply reference points to any or all taxa in the ecosystem. ICES (2000) have contended that even if this was practical for a significant number of taxa, it may not ensure adequate protection of all the ecosystem components at risk. There is a need, therefore, to develop reference points for system level emergent properties as a measure of ecosystem health (Hall, 1999a; Gislason et al., 2000).

ECOSYSTEM MODELLING

There are many recent developments in building of trophic models of aquatic ecosystems. Such modelling can now be performed more rapidly and rigorously than ever before, providing a basis for viable and practical simulation models that have real predictive power (Christensen and Pauly, 1993; Walters et al., 1997). This was made possible by the development of ECOPATH (Polovina, 1984; Christensen and Pauly, 1992), for construction of mass-balance models of ecosystems, based mainly on diet composition, food consumption rates, biomass and mortality estimates.

Such ecosystem models can describe the biomass flows between the different elements of the exploited ecosystems, and can provide answers to 'what if' questions regarding the likely outcome of alternate fishing policies. The ECOPATH suite of software has now been modified (Walters et al., 1997, 2000) to include ECOSIM (simulation module) and ECOSPACE (spatial module). These new routine have not only increased the quantitative power of the approach, but have also allowed qualitatively new questions to be asked.

Ecopath applications to ecosystems, ranging from low latitude areas to the tropics, and from ponds, rivers, and lakes to estuaries, coral reefs, shelves, and the open sea, but all using the same metrics, allowed identification of several general features of aquatic ecosystems:

Multivariate comparisons demonstrated the basic soundness of E. P. Odum's (1969) theory of eco-system maturation (Christensen, 1995b), including a confirmation of his detailed predictions regarding ecosystems near carrying capacity (Christensen and Pauly, 1998). Conversely, this theory can now be used to predict the effect of fisheries on ecosystems, which tend to reduce their maturity, as illustrated by the comparison of Ecopath models for the Eastern Bering Sea in the 1950s and early 1990s (Trites *et al*., 1999a, b), and to guide ecosystem rebuilding strategies implied in ''Back to the Future'' approaches (Pitcher, 1998; Pitcher *et a*l., 2000).

The importance (relative to fishing) of predation by fish and marine mammals within marine ecosystems as suggested by complex models in a few areas (North Sea – Andersen and Ursin, 1977; North Pacific – Laevastu and Favorite, 1977) was confirmed globally by Ecopath models (Christensen, 1996; Trites *et al*., 1997).

Identification of trophic levels as functional entities rather than as concepts for sorting species (Lindeman, 1942; Rigler, 1975) implied the use of non-integer values (computed as 1+ the mean trophic level of the preys, as proposed by Odum and Heald, (1975) that express degree of omnivory (Christensen and Pauly, 1992a), i.e., the extent to which feeding occurs at different trophic levels (Pimm, 1982). Also, trophic level estimated from analyses of stable isotopes of nitrogen has been shown to correlate well with estimates from Ecopath models (Kline and Pauly, 1998).

Estimates of transfer efficiencies between trophic levels (Christensen and Pauly, 1993b; Pauly and Christensen, 1995), previously a matter of conjecture usually pertaining to single-species populations or even to studies of a few individual animals (Slobodkin, 1972), differed radically from earlier guesses by ecosystem types (Ryther, 1969) used for inferences on the potential yields of fisheries (Pauly, 1996), even though the mean was unsurprising (about 10%; Morowitz, 1991).

PERFORMANCE MEASURES

It is generally agreed that reductions in single species fishing mortality levels is perhaps the most significant step one could take towards ensuring the persistence of marine ecosystems (Hall and Mainprize, 2004). It is also clear that ecosystem based fisheries management is still in its formative years, although substantial developments have been seen in some countries and regions. Among these, North America, Antarctica, Europe, Australia and New Zealand are the most notable.

Unfortunately, despite the legislative imperative and clearly articulated principles (Table 2), arriving at an operational framework for an ecosystem-based approach to fisheries management is fraught with difficulties. This difficulty is due, not only to the inherent challenge in establishing and quantifying the effects of fishing at an ecosystem level, but also due to the social and political dimensions associated with harvesting fisheries at an environmentally sustainable level.

Table 2. The six principles for an ecosystem based fisheries management approach (adapted from Inter-agency Marine Fisheries Working Group, 2002)

Principle	Description
Ecosystem identification	The ecosystem that fisheries will be managed within need to be defined on the basis of the main physical, biological and human dependency relationships
Clear objectives	Objectives for fisheries management shall have regard to local and national needs, and management should be decentralized to the maximum extent possible
Long term benefits	Ecosystem based management should aim for long term benefits – management should look to restore stocks to levels that are capable of delivering optimal yields over the long term; and achieving such yields should not compromise other marine species and habitats. Management should also aim to support biological biodiversity
Incentives aligned with and ecosystem based approach	Incentives should be realigned to support aims of the ecosystem based approach – incentives and financial support needs to be redirected from fisheries that aim at increasing fishing efficiency to those that make concerted efforts to those that promote the restoration of fish stocks to optimal yield levels and which support responsible fishing practices in sensitive marine areas
Easily assessed information and alternate management options	Information necessary to implement the ecosystem based approach should be made available to all. Where information is insufficient, adaptive management and the precautionary approach should be followed. If the outcome falls short of what was intended the management decisions should be suitably altered – proactive management

Trophic Modelling Studies in India

Trophic modelling studies in Indian aquatic ecosystems are few. The first preliminary attempts were made using ECOPATH II in a small ecosystem in Veli Lake near Thiruvananthapuram (Aravindan, 1993) and an estuarine ecosystem along the southeast coast of India (Santhanam et al., 1993). Subsequently, another preliminary attempt was made to model the southwest coast ecosystem using already existing data and many assumptions (Vivekanandan et al. 2003). In 2004, the CMFRI organised and conducted a 21-day Winter School on 'Towards ecosystem based fisheries management of marine fisheries – Building mass balance trophic and simulation models for 25 national level participants (Mohamed 2004). This ultimately led to the development of a trophic model for a dam in Andhra Pradesh (Panikker and Khan, 2008). Currently the CMFRI is undertaking a project to model the Gulf of Mannar (GOM) and North West Coast (NWC) ecosystems, besides it has incorporated collection of trophic modelling parameters in all its capture fisheries management projects.

Background

Karnataka State along the southwest coast of India has a 300 km coastline and is one of the frontline States of India in marine fisheries development. Historically known as the *mackerel coast*, it has a continental shelf area of 27,000 km^2. The State's contribution to the total marine fish production of India has varied from 6 to 14 % annually. Karnataka State has been a pioneer in the introduction of new mechanized fishing technologies, development of fishing harbours and improvement in the living standards of fishermen (25,000 fishers, 1980 census). Consequently, the State has the largest purse seine fleet in India and its trawl fleet is comparatively modern and dynamic. The introduction of new and more efficient gears had resulted in steep increase in marine fish production in the State during the seventies and eighties. However, in the nineties, the catches and catch rates have fallen/stabilised for major gears like purse seine and trawl resulting in reduction of profit for the fishermen and revenue for the State (Mohamed et al., 1997).

The State has three coastal districts, Dakshina Kannada (DK), Udupi and Uttara Kannada (UK). More than a dozen rivers originating in the Western Ghats open into the Arabian Sea in these three districts rendering the inshore waters highly productive. Pelagic species like mackerel and sardines and demersal finfishes, prawns and cephalopods are landed in 28 fish landing centres along the coast. There are 5 major harbours and 4 medium harbours in the region. More than 90% of the State's marine fish production comes from the major ports of Mangalore in DK district, Malpe in Udupi district and Honavar, Tadri and Karwar in UK district. These centres cater almost exclusively to the mechanized fishing sector, the principal gears being trawl (single day and multi-day), purse seine (PS), gillnet (GN), hook and line (H&L) and artisanal (AS) in addition a few small longliners. Mechanized trawl fishing in the region is carried out principally by two fleets (Zacharia et al., 1996). The multi-day fleet (MDF), whose number is growing at a fast pace in the State, undertakes voyages lasting upto 7 days in depths upto 200 m. Recently multi-day longliners are also operated from these centres principally for sharks. The purse seine fleet is mainly concentrated in the major harbours. Of late, some of them are functioning as combination vessels (purse seining during the peak pelagic season and multi-day trawling during rest of the season). The largest fleet in all harbours is the small coastal trawlers (single day fleet (SDF) - 30-32 footers) operating on a daily basis in the near shore areas upto 25 m depth. Their number is decreasing due to dwindling profits and no fleet additions have taken place during the last few years.

The State has developed sufficient infrastructure to process and market its marine fish production. In total, the State has 98 ice plants, 35 cold storages, 22 freezing plants, 10 canning plants, 21 fishmeal plants and 4 fish oil plants. The large number of ice plants and their production capacity of 1296 tonnes/day are primarily because of the substantial intake of ice by the multi-day trawlers for their voyages. Besides, there are 68 primary fisheries co-operative societies and 2 co-operative fish marketing federations in the three coastal districts.

During the period 1956-2003 the average marine fish production in the State was estimated as 123,043 tonnes (t). Production peaks were noticed in 1960, 1964, 1970, 1978, 1982, 1989 and 2002. From 1989, there has been a steep decline, after which production peaked again in 2002. The production peak in 1978 and subsequent peaks are mainly due to the introduction of purse seiners and their rapid expansion in the State. The average decadal marine fish production in the State is shown in Table 3.

Table 3. Average marine fish production in Karnataka and production per km of coastline compared to national average.

Period	*Karnataka Average (t)*	*Production per km coast(t)*	*National Average (t)*	*National production per km*
Fifties	57,359	191.2	634,227	84.4
Sixties	63,119	210.4	812,593	108.1
Seventies	104,026	346.8	1,249,240	166.2
Eighties	165,398	551.3	1,607,327	213.8
Nineties	157,514	525.0	2,252,268	299.6
Two thousands	190,841	636.1	2,557,797	340.2

The fall in production from 1989 to 1995 is over 100,000 t and the fall in average production from eighties to nineties is about 7000 t. The production rate (marine fish production/km coastline) of the State is almost double the national average right from the 1950s (Table.3). The rate of increase has been steep during seventies and eighties, mainly due to the very efficient exploitation of the pelagic resources by the purse seine fleet. The transition from 1980s to 90s showed a decline in the production rate of the State, although the national average moved up.

Fisheries and biological research on marine resources of the State has been principally done by the CMFRI (Central Marine Fisheries Research Institute) since the late fifties. Biological studies have indicated the breeding season of all important fish stocks. The spawning stock biomass and stock replacement levels have been studied with respect to mackerel (Devaraj *et al*., 1994), squid (Mohamed and Rao, 1997) and threadfin bream (Zacharia, unpublished) stocks of the State. Assessment of biomass and MSY of all important fish stocks in the State has been carried out using production and/or analytical models. The largely F-based models used indicate that many commercially important stocks like prawns, squids and demersal finfishes like whitefish, lizardfishes and catfishes are overexploited and the effort level needs to be reduced. The marine fishery along the Karnataka coast is very dynamic in nature particularly with year-to-year expansion in grounds and decreasing mesh sizes. Nonetheless, a reduction in fishing effort for PS and TR fleets is warranted as past studies indicate such a necessity for most species groups. Conversely, studies also indicated that the some of the stocks are under-exploited and their exploitation level could be stepped up by increasing the effort level. However, because of the multispecies/ multigear nature of the fisheries, single species dynamics has little practical utility for making resource management decisions.

Fisheries scientists throughout the world largely agree that they must find ways to account for species interactions. The emerging shift of fisheries research from single-species analysis towards an ecosystem-based approach requires tools that explicitly account for ecological interactions, especially those of a trophic nature. Two such tools, which are employed, are Ecopath and Ecosim (Christensen and Pauly 1992a, b, 1995; Walters et al. 1997). These are software packages that explicitly describe trophic relationships between marine species and simulate changes over time.

Therefore, attempts were made to direct new research toward management of the resources using the ecosystem concept through an Indian Council of Agricultural Research (ICAR) AP-Cess Fund project. Although initially envisaged as a mass balance model for southern Karnataka, during the course of the work it was expanded to cover the entire Karnataka state. The ECOPATH with ECOSIM software was used in the present exercise to construct the mass-balance ecosystem model.

An Overview of Ecopath & Ecosim

The Ecopath software is a simple approach for analyzing trophic interactions in fisheries resources systems (Christensen and Pauly 1992a,b, 1995). Ecopath is based on the earlier work of Polovina (1984), and is being widely applied to aquatic systems (Christensen and Pauly 1993, Pauly and Christensen 1995). It is a mass-balance approach that describes an ecosystem at steady-state for a given period. Further development of this steady-state model has resulted in a dynamic ecosystem model called Ecosim that is capable of simulating ecosystem changes over time (Walters et al., 1997). Ecopath and Ecosim represent all of the major components of the ecosystem, and their feeding interactions, but are relatively simple. These kinds of models readily lend themselves to answering simple, ecosystem wide questions about the dynamics and the response of the ecosystem to anthropogenic changes. Thus, they can help design policies aimed at implementing ecosystem management principles, and can provide insights into the changes that have occurred in ecosystems over time. Ecopath models rely on the truism that:

Production = biomass accumulation + fisheries catch + mortality due to predation + other mortality + loss to adjacent systems.

This applies for any producer (e.g., a given fish population) and time (e.g., a year or season). Groups are linked through predators consuming prey, where:

Consumption = production + non-assimilated food + respiration.

The implication of these two relationships is that the system or model is mass balanced (i.e., biomass is 'conserved', or accounted for in the ecosystem). This principle of mass conservation provides a rigorous framework – formalized through a system of linear equations – through which the biomass and trophic fluxes among different consumer groups within an ecosystem can be estimated (Christensen and Pauly 1995). Constructing an Ecopath model emphasizes ecological relationships rather than mathematical equations. All that is required are the types of data that are routinely collected by fisheries scientists and marine biologists. The model can incorporate and standardize large amounts of scattered information – information that might have otherwise languished in scattered journals, reports and filing cabinets (Christensen and Pauly 1995).

Ecopath is essentially a large spreadsheet that is simultaneously keeping track of all the species and all the feeding interactions occurring within the ecosystem. It describes the ecosystem at one point in time. Ecosim, which is based on the Ecopath equation, simulates how a change in one or more components might affect the ecosystem over time.

Ecopath and Ecosim have been widely applied in recent years. More than 80 Ecopath systems have so far been published world-wide. They span a diversity of systems including upwelling, shelves, lakes and ponds, rivers, open oceans and even terrestrial farming systems (see Christensen and Pauly 1992a,b, 1995; Walters et al. 1997; and the Ecopath home page at http:// www.ecopath.org).

Principles of the Ecopath Model

The core routine of Ecopath is derived from the Ecopath program of Polovina (1984), and since modified to make superfluous its original assumption of steady state. Ecopath no longer assumes steady state but instead bases the parameterization on an assumption of mass balance over an arbitrary period, usually a year. In its present implementation Ecopath parameterizes models based on two master equations, one to describe the production term and one for the energy balance for each group.

The first Ecopath equation describes how the production term for each group (i) can be split in components. This is implemented with the equation,

Production = catches + predation mortality + biomass accumulation + net migration + other mortality; or, more formally,

$$P_i = Y_i + B_i \cdot M2_i + E_i + BA_i + P_i \cdot (1 - EE_i)$$

Eq. 1

where Pi is the total production rate of (i), Yi is the total fishery catch rate of (i), M2i is the total predation rate for group (i), Bi the biomass of the group, Ei the net migration rate (emigration - immigration), BAi is the biomass accumulation rate for (i), while M0i = Pi · (1-EEi) is the other mortality rate for (i).

This formulation incorporates most of the production (or mortality) components in common use, perhaps with the exception of gonadal products. Gonadal products however nearly always end up being eaten by other groups, and can be included in either predation or other mortality.

Eq. 1 can be re-expressed as

$$B_i \cdot (P/B)_i \cdot EE_i - \sum_{j=1}^{n} B_j \cdot (Q/B)_j \cdot DC_{ji} - Y_i - E_i - BA_i = 0$$

Eq. 2

where: P/Bi is the production/biomass ratio, Q/Bi is the consumption/biomass ratio, and DCji, is the fraction of prey (i) in the average diet of predator (j).

Of the terms in Eq. 2 the production rate, Pi, is calculated as the product of Bi, the biomass of (i) and Pi/Bi, the production/biomass ratio for group (i). The Pi/Bi rate under most conditions corresponds to the total mortality rate, Z, see Allen (1971), commonly estimated as part of fishery stock assessments. The other mortality is a catch-all term including all mortality not elsewhere included, e.g., mortality due to diseases or old age, and is internally computed from,

$$M0_i = P_i \cdot (1 - EE_i)$$

where EEi is called the ecotrophic efficiency of (i), and can be described as the proportion of the production that is utilized in the system. The production term describing predation mortality, M2, serves to link predators and prey as,

$$M2_i = \sum_{j=1}^{n} Q_j \cdot DC_{ji}$$

Eq. 3

where the summation is over all (n) predator groups (j) feeding on group (i), Qj is the total consumption rate for group (j), and DCji is the fraction of predator (j) diet contributed by prey (i). Qj is calculated as the product of Bj, the biomass of group (j) and Qj/Bj, the consumption/biomass ratio for group (j).

An important implication of the equation above is that information about predator consumption rates and diets concerning a given prey can be used to estimate the predation mortality term for the group, or, alternatively, that if the predation mortality for a given prey is known the equation can be used to estimate the consumption rates for one or more predators instead.

For parameterization, Ecopath sets up a system with (at least in principle) as many linear equations as there are groups in a system, and it solves the set for one of the following parameters for each group:

- biomass;
- production/biomass ratio;
- consumption/biomass ratio; or
- ecotrophic efficiency.

while the other three parameters along with following parameters must be entered for all groups:

- catch rate;
- net migration rate;
- biomass accumulation rate;
- assimilation rate; and
- diet compositions.

It was indicated above that Ecopath does not rely on solving a full set of linear equations, i.e., there may be less equations than there are groups in the system. This is due to a number of algorithms included in the parameterization routine that will try to estimate iteratively as many missing parameters as possible before setting up the set of linear equations.

ECOSIM – Dynamic mass-balance approach for Ecosystem Simulation

By converting the linear equations of Ecopath models to differential equations, Ecosim provides a dynamic mass-balance approach, suitable for simulation (Walters et. al., 1997). Constructing a dynamic model from equation (1) there are three changes viz; (a) replace the left side with a rate of change of biomass; (b) for primary producers, provide a functional relationship to predict changes in (P/Bi) with biomass Bi (representing competition for light, nutrients and space); and (c) replace the static pool-pool consumption rates with functional relationships predicting how consumption will change with changes in biomass of Bi and Bj. The basics of ECOSIM consist of biomass dynamics expressed through a series of coupled differential equations. The equations are derived from the ECOPATH master equation (Eq.1), and take the form

$$dB_i / dt = g_i \sum_j C_{ji} - \sum_j C_{ij} + I_i - (M_i + F_i + e_i) B_i$$

Eq. 4

where dBi/dt represents the growth rate during the time interval dt of group (i) in terms of its biomass, Bi, gi is the net growth efficiency (production/consumption ratio), Mi the non-predation (other) natural mortality rate, Fi is fishing mortality rate, ei is emigration rate, Ii is immigration rate, (and ei·Bi-Ii is the net migration rate). The two summations estimates consumption rates, the first expressing the total consumption by group (i), and the second the predation by all predators on the same group (i). The consumption rates, Cji, are calculated based on the foraging arena concept, where Bi.s are divided into vulnerable and nonvulnerable components (Walters et al. 1997), and it is the transfer rate (vij) between these two components that determines if control is top-down (i.e., Lotka-Volterra), bottom-up (i.e., donor-driven), or of an intermediate type. The set of differential equations is solved in Ecosim using (by default) an Adams-Basforth integration routine or (if selected) a Runge-Kutta 4th order routine.

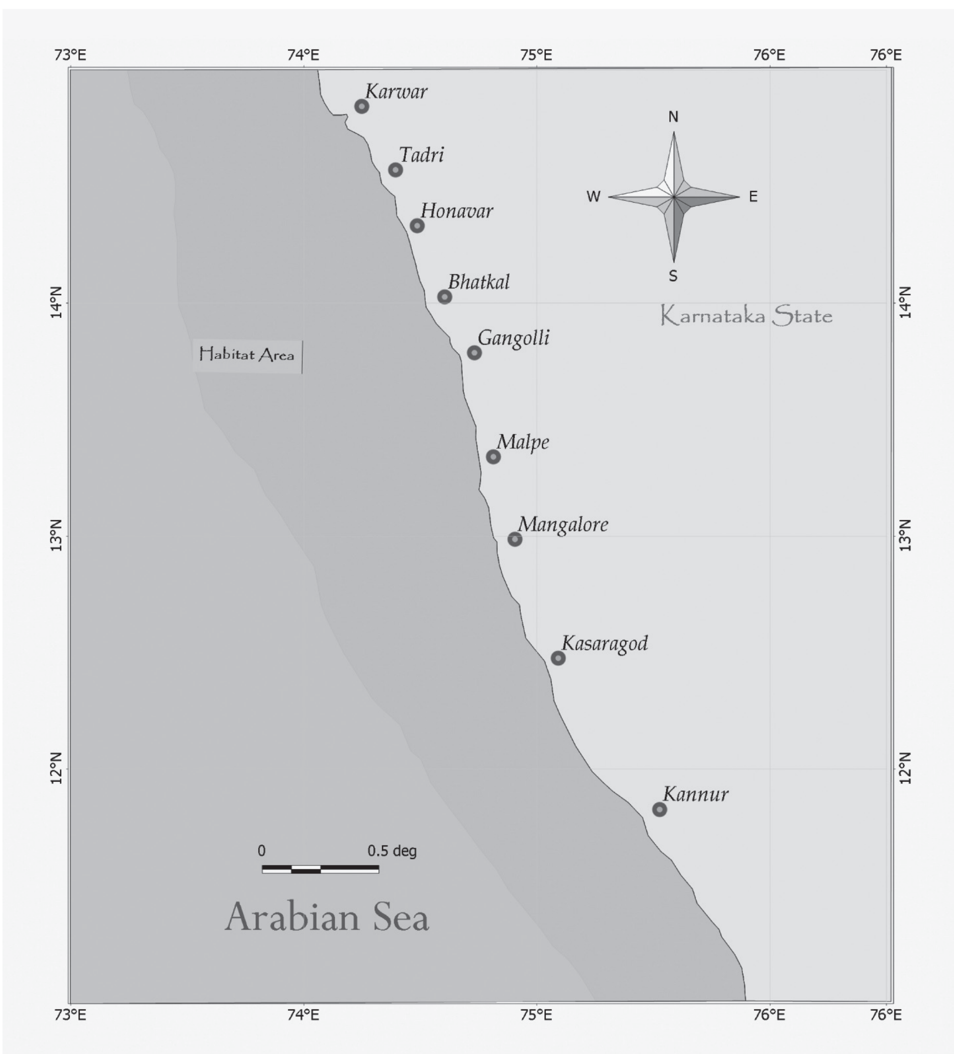
Using previously constructed Ecopath models, Ecosim calculates corresponding changes in biomass of each component when the fishing mortality of any particular group is altered. These dynamic simulations are plotted as coloured biomass curves. The scale differs for each curve. By altering the rate of flow between vulnerable and nonvulnerable prey different functional relationships for predators and prey can be considered. These can range from pure donor control, where the prey availability governs interactions, to top-down control where predation pressure dominates. Using equilibrium simulations, where equilibrium biomass is plotted over a range of F values, Ecosim provides the facility to predict the potential equilibrium yield for the fished group.

Data Collection & Methodology

Study Area – Defining the System

Situated along the west coast of India facing the Arabian Sea, Karnataka State has a coastline measuring 300 km. The marine ecosystem of the state can be referred to as a tropical upwelling zone within the latitudinal limits of 12 and 15°N and 73 and 76°E. Netravati, Gurupur, Mulki, Sitanadi, Coondapur, Aghanasini, Kali and Sharavati are the important rivers. The estuaries formed by these rivers are important from the ecological and biological points of view. The state is well forested and characterised by rich floral and faunal diversity. The weather is hot and humid during most part of the year. The average annual rainfall is about 4000 mm of which 80% is received during June-September. The bottom topography of the sea is typically muddy to sandy with few rocky patches. It covers a wide range of marine habitats that includes the continental shelf and parts of the slope, but it was treated as a single homogenous area. The marine fishery of Karnataka overlaps into the neighbouring states of Goa in the north and Kerala in the south and exploitation takes place up to a depth of 200m. The habitat area for the present study was taken as 27000 km^2 on the basis of the exploitation pattern of Karnataka based fishing fleets.

The general hydrographic features along the west coast of India including Karnataka state were given by Madhupratap *et al.* (2001). During spring inter-monsoon period (March-May) the entire Arabian Sea has very low primary productivity (14-21 mgC



m^{-2} d^{-1}). During this period, the Arabian Sea attains typical tropical structure. Similar scenario prevails during September-October when transition of summer to winter monsoon occurs. These periods have higher sea surface temperature (=28 ^{0}C), shallow mixed layer depth at 20-30m depth and strong stratification. Nutrients especially nitrates are at undetectable levels in the surface waters. With the onset of summer monsoon (June-September) the situation changes considerably under the influence of southwesterly winds along the west coast, surface water moves away from the coast and is replaced by colder nutrient rich oxygen depleted water from sub-surface. This leads to phytoplankton blooms and increased primary productivity. Upwelling starts at southern tip of west coast by May/early June and progresses to northwest with time. This phenomenon lasts up to end of August/ early September. During this period, a low level jet current flows across Arabian Sea from north of Africa to northern India.

While high biological productivity, both primary and secondary is reported in these waters during and after upwelling (Devassy, 1983), high benthic production is noticed during the late post-monsoon (Harkantra and Parulekar, 1981). About 40 to 60% of total annual fish production in Karnataka is realized during October-December, which consists mainly of planktivorus fishes like clupeids, mackerel and anchovies. The coastal upwelling of nutrients occurring during the southwest monsoon supports the rich fisheries in this region during post-monsoon season (De Sousa *et al.*, 1996).

Fishery Catch & Effort Data

Fish landing data collected from 1999 to 2001 by the FRAD survey staff of CMFRI following the stratified random multi-stage marine fish landing survey method was used for the study. Catch and effort data was collected from all important landing centres of Karnataka including Mangalore and Malpe, which together land more than 40% of the state's marine fish landings. Catch and effort data from purse seine (PS), single day (SDF) and multi-day trawlers (MDF) drift gill net (GN), hook and lines (H&L) and (AS) gears were used. The MDF, whose number is growing at a fast pace in the State; undertake voyages lasting up to 7 days in depths up to 200 m. The largest fleet in all harbours is the small coastal trawlers SDF (30-32 footers) operating on a daily basis in the nearshore areas upto 25 m depth. Their number is decreasing due to dwindling profits

Table. Estimated resource-wise all-gear catch from Karnataka in tonnes
(source: FRAD, CMFRI, Cochin)

	Name of Resource	1999	2000	2001	Total	Average
1	Sharks	716	813	954	2483	828
2	Skates	72	4	91	167	56
3	Rays	160	250	215	625	208
4	Eels	209	82	123	414	138
5	Catfishes	244	144	402	790	263
6	Wolf herring	242	161	363	766	255
7	Oil sardine	21085	33293	40757	95135	31712
8	Other sardines	3096	983	2552	6631	2210
9	Hilsa shad	2	92	13	107	36
10	Other shads	0	0	226	226	75
11	*Coilia*	18	15	34	67	22
12	*Stolephorus*	4991	5977	5231	16199	5400
13	*Thryssa*	3272	1721	3204	8197	2732
14	Other clupeids	1836	1779	2667	6282	2094
15	LIZARD FISHES	2203	3532	4049	9784	3261
16	HALF BEAKS&FULL BEAKS	300	153	299	752	251
17	Rock cods	2575	2879	4953	10407	3469
18	Snappers	123	31	22	176	59
19	Pigface breams	70	0	0	70	23
20	Threadfin breams	11704	18398	24925	55027	18342
21	Other perches	4009	3993	6758	14760	4920
22	GOATFISHES	15	188	13	216	72
23	THREADFINS	0	0	1	1	0
24	CROAKERS	3286	3068	3374	9728	3243
25	RIBBON FISHES	2666	11906	4569	19141	6380
26	Horse Mackerel	3634	1380	2116	7130	2377

27	Scads	3286	3059	5424	11769	3923
28	Leatherjackets	365	109	438	912	304
29	Other carangids	8150	5124	4757	18031	6010
30	SILVERBELLIES	2753	1602	2738	7093	2364
31	Lactarius	1066	1256	1250	3572	1191
32	Black pomfret	934	866	1346	3146	1049
33	Silver pomfret	466	546	312	1324	441
34	Chinese pomfret	1	24	29	54	18
35	Indian mackerel	36666	22153	17759	76578	25526
36	*S. commerson*	2019	3442	2204	7665	2555
37	*S. guttatus*	274	1148	332	1754	585
38	*E. affinis*	1722	2993	1289	6004	2001
39	*Auxis* spp	137	1232	950	2319	773
40	*K. pelamis*	0	0	0	0	0
41	*T. tonggol*	363	110	59	532	177
42	Other tunnies	0	267	90	357	119
43	BILL FISHES	18	91	70	179	60
44	BARRACUDAS	1335	1428	1760	4523	1508
45	MULLETS	61	40	79	180	60
46	Halibut	138	130	32	300	100
47	Flounders	0	0	41	41	14
48	Soles	6636	14194	10915	31745	10582
49	Penaeid prawns	8893	6592	8902	24387	8129
50	Nonpenaeid prawns	1	284	5	290	97
51	Lobsters	2	49	46	97	32
52	Crabs	1118	1854	1971	4943	1648
53	Stomatopods	13136	12650	12630	38416	12805
54	Bivalves	0	72	1015	1087	362
55	Cephalopods	8089	8886	5568	22543	7514
56	Dolphin & Porpoise	9	0	7	16	5
57	MISCELLANEOUS	932	1871	1491	4294	1431
	TOTAL	**165098**	**182914**	**191420**	**539432**	**179811**

and no fleet additions have taken place during the last few years. The gear-wise monthly catch and effort data was suitably raised to obtain landing for entire Karnataka.

Length Frequency Data

Length frequency measurements of commercial species landed was collected regularly by field visits to Mangalore and Malpe, the two important mechanised landing centres of Karnataka, which together land more than 40% of the state's marine fish landings. On each observation day measurements were taken on field and for detailed biological and stomach content analysis samples were brought to the laboratory for detailed biological analysis length–weight relationship and diet analysis. Total length (TL) was measured and the length measurements were appropriately grouped into length classes (2 cm for big fishes, 1 cm for medium fishes and 0.5 cm for small fishes) and used as input for growth and mortality estimates in FiSAT software.

Stomach Content Data & Diet Matrix

The study of stomach contents can give insight into the marine food chain in view of competition between species and will be helpful in evaluating the predator-prey relationship. For studying the dynamics of food and feeding habits of marine fishes a combination of numerical and volumetric methods would give better picture of food than when each of these methods is applied in isolation (Qasim, 1972). The index of pre-ponderance method (Natarajan and Jhingaran, 1961) takes into account both the frequency of occurrence as well as bulk of the food item (volume) providing a definite and measurable basis for grading different food items.

Samples were collected once a week from landings at Mangalore, Malpe landing centres. After washing, each fish was measured (total length -TL) and weighed (to the nearest g). After cutting open the abdomen, the sex, maturity stage and degree of fullness of stomachs were recorded. The variations in the fullness were classified as full, ¾ full, ½ full, ¼ full, traces and empty. The stomachs of fishes were removed, weighed and preserved in 7% buffered formalin for further analysis. The contents of the stomach were separated into groups and weights taken to the nearest mg. A total of 9786 fishes and shellfishes belonging to 56 species were analysed for this purpose.

The index of relative importance (IRI) as described by Pinkas et al. (1971) was used since combining values from direct sources are more representative. The IRI was calculated as given below:

$$IRI = (\%N + \%V) \times \%F$$

where, N = number, V = volume and F = frequency of occurrence.

The diets of different fishes were quantitatively expressed (see appendix) and later pooled ecological group-wise to derive the diet matrix, which was used as input (original diet matrix in appendix) for Ecopath run.

Ecological Groupings

Ecological groupings were made taking into consideration that within group, the species have similar sizes, similar population parameters, similar food and similar predators. Under these assumptions, the resources were grouped into 24 ecological groups for ECOPATH analysis. The ecological groups were Marine mammals (Dolphins), Sharks, Skates and Rays, Large Pelagics (seers, kingfish and barracudas), Tunas, Cephalopods (squids and cuttlefish), Large Benthopelagics (ribbonfish, horse mackerel, catfish, wolf herring and queenfish), Large Benthic Carnivores (rock cods, jobfish, lizardfishes, red snappers), Medium Benthic Carnivores (sciaenids, flatheads, bull's eye, pomfrets, balistids, flounders), Small Benthic Carnivores (threadfin breams, terapons, whitefish, silverbellies, goatfishes, cardinalfish, *Uranoscopus* sp and tetradon), Small Benthopelagics (scads, carangids, moonfish and myctophids), Mackerel, Clupeids (oil sardine, lesser sardines, rainbow sardines, *Thryssa* , white sardine, *Pellona*), Anchovies and unicorn cod, Crabs and lobsters, Shrimps, Benthic Omnivores (soles, cornetfish, squilla), Heterotrophic Benthos (epifauna- bivalves, gastropods, echinoderms, benthic crabs, amphipods and isopods), Meiobenthos (benthic infauna-annelids, polychaetes, foraminiferans and hydrozoans, Micro-nekton (jellyfish, juveniles of fishes), Large Zooplankton, Micro-zooplankton (fish eggs, decapod eggs and larva, bivalve larva and tintinnids), phytoplankton and detritus. Detailed list of species in each group is given in table.

Table: Components of Ecological Groupings

Grp1	**Marine mammals**	
	1	*Tursiops truncatus*
	2	*Sousa chinensis*
	3	*Delphinus delphis*
Grp2	**Sharks**	
	4	*Rhizoprionodon acutus*
	5	*Carcharinus limbatus*
	6	*Scoliodon laticaudus*
	7	*Sphyrna lewini*
Grp3	**Stakes & Rays**	
	8	*Rhinobatos granulatus*
	9	*Rhinoptera javanica*
	10	*Dasyatis* sp.
Grp4	**Large Pelagics**	
	11	*Scomberomorus commerson*
	12	*S. guttatus*
	13	*Rachycentron canadum*
	14	*Sphyraena obtusata*
	15	*S. jello*
Grp5	**Tunas**	
	16	*Euthynnus affinis*
	17	*Thunnus tonggol*
	18	*Auxis thazard*
	19	*A. rochei*
Grp6	**Cephalopods**	
	20	*Loligo duvauceli*
	21	*Sepia pharaonis*
	22	*S. elliptica*
	23	*Sepiella inermis*
Grp7	**Large Benthopelagics**	
	24	*Trichiurus lepturus*
	25	*Megalaspis cordyla*
	26	*Scomberoides tol*
	27	*Chirocentrus dorab*
	28	*Tachysurus* sp.
Grp8	**Large Benthic Carnivores**	
	29	*Epinephelus diacanthus*
	30	*Pristipomoides filamentosus*
	31	*Saurida tumbil*
	32	*S. undosquamis*
	33	*Serranus* sp.
	34	*Lutjanus* sp.
Grp9	**Medium Benthic Carnivores**	
	35	*Johnieops sina*
	36	*Otolithes ruber*
	37	*Grammoplites suppositus*
	38	*Pampus argenteus*
	39	*Formio niger*
	40	*Priacanthus hamrur*

	41	*Polynemus sp.*
	42	*Dactyloptera sp.*
	43	*Pseudorhombus arsius*
	44	*P. natalensis*
	45	Balistids
Grp10	**Small Benthic Carnivores**	
	46	*Nemipterus japonicus*
	47	*N. mesoprion*
	48	*Therapon* sp.
	49	*Lactarius lactarius*
	50	*Secutor insidiator*
	51	*Leiognathus bindus*
	52	*Upeneus* sp.
	53	*Apogon* sp.
	54	*Uranoscopus* sp.
	55	*Tetradon* sp.
Grp11	**Small Benthopelagics**	
	56	*Decapterus russelli*
	57	*D. macrosoma*
	58	*Caranx kalla*
	59	*Mene maculata*
	60	Myctophids
Grp12	**Mackerel**	
	61	*Rastrelliger kanagurta*
Grp13	**Clupeids**	
	62	*Sardinella longiceps*
	63	*S. fimbriata*
	64	*S. gibbosa*
	65	*Thryssa mystax*
	66	*Dussumieria acuta*
	67	*Escualosa thoracata*
	68	*Pellona sp.*
	69	*Opisthopterus tardoore*
Grp14	**Anchovies**	
	70	*Stolephorus devisi*
	71	*S. waitei*
	72	*S.commersonii*
	73	*S. indicus*
	74	*Bregmaceros mcclellandi*
Grp15	**Crabs and Lobsters**	
	75	*Portunus sanguinolentus*
	76	*P. pelagicus*
	77	*Charybdis cruciata*
	78	*Panulirus* sp.
Grp16	**Shrimps**	
	79	*Metapenaeus monoceros*
	80	*M. dobsoni*
	81	*Parapenaeopsis stylifera*
	82	*Solenocera choprai*
	83	*Trachypenaeus* sp.
	84	*Aristeus* sp.
Grp17	**Benthic Omnivores**	
	85	*Cynoglossus macrostomus*
	86	*Plotosus* sp.
	87	*Fistularia* sp.
	88	*Oratosquilla nepa*
Grp18	**Heterotrophic Benthos (Epifauna)**	
	89	*Bivalves*
	90	*Gastropods*
	91	*Echinoderms*
	92	*Benthic crabs*
	93	*Amphipods*
	94	*Isopods*
Grp19	**Meiobenthos (Infauna)**	
	95	*Annelids*
	96	*Polychaetes*
	97	*Foraminiferans*
	98	*Hydrozoans*
Grp20	**Nekton**	
	99	*Jellyfish*
	100	*Juvenile fishes*
	101	*Leptocephalus*
	102	*Eel elvers*
Grp21	**Large Zooplankton**	
	103	*Alima larva*
	104	*Cypris*
	105	*Calanus* sp
	106	*Zoea of crab*
	107	*Megalopa*
	108	*Cladocerans*
	109	*Sagitta*
	110	*Mysids*
	111	*Lucifer larva*
	112	*Medusa*
	113	*Siphonophores*
Grp22	**Micro Zooplankton**	
	114	*Fish eggs*
	115	*Decapod eggs and larvae*
	116	*Bivalve larvae*
	117	*Tintinnids*
Grp23	**Phytoplankton**	
	118	*Fragilaria*
	119	*Coscinodiscus*
	120	*Thalassiothrix*
	121	*Pleurosigma*
	122	*Flavella*
	123	*Asterionella*
	124	*Skeletonema*
	125	*Rhizosolenia*
	126	*Chaetoceros*
	127	*Nitzchia*
	128	*Noctiluca*
	129	*Ceratium*
Grp24	**Detritus**	

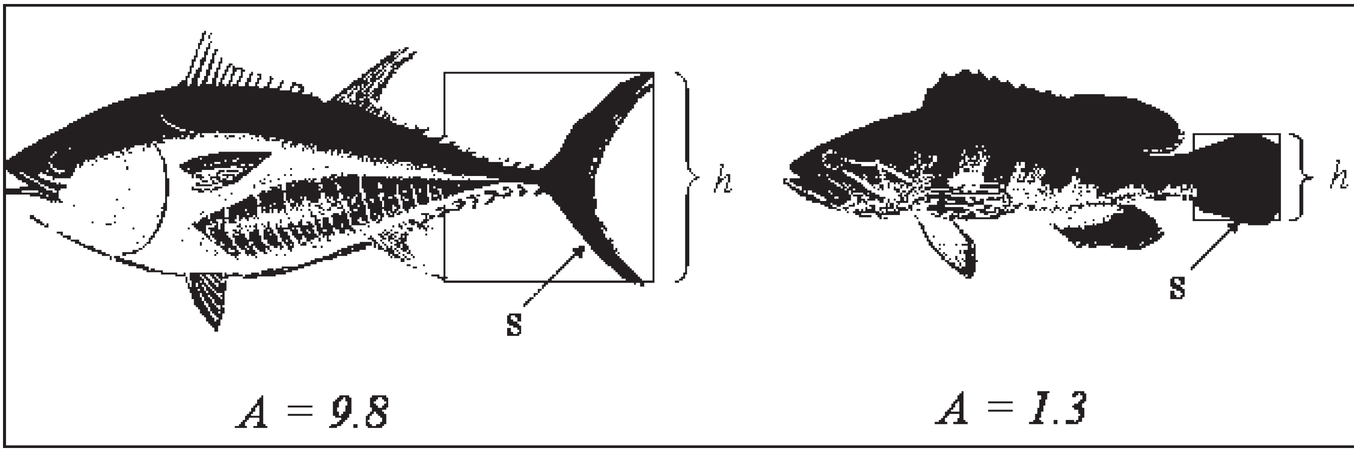
This ecological grouping comprised of 129 species and covered more than 86% of the commercial catches recorded from the area. Based on the ecological grouping the landings were classified in to gearwise catch and expressed as tonnes per square km. The primary data on landing centre prices were also converted into price per tonne per group for each gear.

Table. Estimated average gearwise landings (tonnes/km^2/year) during 1999-2001 used as input for ECOPATH run

Grp No	Group Name	MDF	SDF	PS	GN	H&L	AS	TOTAL
1	Marine Mammals	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Sharks	0.013	0.001	0.000	0.012	0.000	0.004	0.030
3	Skates & Rays	0.005	0.001	0.000	0.001	0.001	0.001	0.009
4	Large Pelagics	0.056	0.003	0.038	0.080	0.000	0.008	0.185
5	Tunas	0.003	0.000	0.085	0.019	0.000	0.006	0.113
6	Cephalopods	0.258	0.015	0.002	0.000	0.000	0.003	0.278
7	Large Benthopelagics	0.217	0.030	0.083	0.010	0.000	0.011	0.351
8	Large Benthic Carnivores	0.242	0.007	0.000	0.002	0.027	0.003	0.281
9	Medium Benthic Carnivores	0.172	0.068	0.027	0.005	0.000	0.058	0.330
10	Small Benthic Carnivores	0.709	0.051	0.008	0.003	0.000	0.045	0.816
11	Small Benthopelagics	0.109	0.030	0.179	0.016	0.000	0.046	0.380
12	Mackerel	0.041	0.001	0.709	0.074	0.000	0.120	0.945
13	Clupeids	0.058	0.039	0.924	0.018	0.000	0.400	1.439
14	Anchovies	0.090	0.009	0.100	0.000	0.000	0.002	0.201
15	Crabs & Lobsters	0.018	0.033	0.000	0.001	0.000	0.009	0.061
16	Shrimps	0.100	0.151	0.004	0.006	0.000	0.045	0.306
17	Benthic Omnivores	0.086	0.746	0.002	0.000	0.000	0.010	0.844
18	Heterotrophic Benthos	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	Meiobenthos	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	Micro Nekton	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	Large Zooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	Micro Zooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sum	2.177	1.185	2.161	0.247	0.028	0.771	6.569

Table. Average group-wise price (Rs) per tonne of resources used as input for ECOPATH run

Group No	Group Name	MDF	SDF	PS	GN	H&L	AS
1	Marine Mammals	0	0	0	10000	0	0
2	Sharks	10000	10000	10000	50000	50000	10000
3	Skates & Rays	25000	20000	20000	20000	20000	10000
4	Large Pelagics	30000	16700	46700	48800	50000	20000
5	Tunas	16000	15000	19000	18800	0	16000
6	Cephalopods	45700	40500	45000	45000	0	20000
7	Large Benthopelagics	17200	14000	20200	20200	0	15000
8	Large Benthic Carnivores	16400	10000	10000	12500	15000	6000
9	Med Benthic Carnivores	42100	34200	41700	33500	0	40000
10	Small Benthic Carnivores	19400	18000	7000	8000	0	8000
11	Small Benthopelagics	8500	7500	8500	8500	8500	5000
12	Mackerel	20000	25000	30000	20000	0	40000
13	Clupeids	5500	10600	5300	5300	0	23000
14	Anchovies	10000	15000	15000	0	0	15000
15	Crabs & Lobsters	20000	30000	0	20000	0	30000
16	Shrimps	113000	27500	70000	27500	0	70000
17	Benthic Omnivores	9000	3000	3000	0	0	6000



Estimates of P/B

Production/biomass ratio, P/B is equivalent to the instantaneous rate of total mortality *(Z)* [Allen, 1971]. The *Z* values estimated for all species using the length converted catch curve routine in FiSAT. The estimated P/B values and other population parameters are given in the Species Life History Sheets.

Estimates of Q/B

Consumption/biomass or Q/B is the annual food consumption/ biomass ratio of each group and it was determined by the following empirical equation [Pauly et al., 1998]:

$$\log Q/B = 7.964 - 0.204 \log W_{\infty} - 1.965.\ T + 0.083.\ A + 0.532.h + 0.398.d \qquad \textbf{(Eq. 5)}$$

where W_{∞} is the asymptotic weight of the species (wet weight in g), which can be obtained from the asymptotic length using length–weight relationship; h and d are the binary variables for the types of food consumed (0 for carnivores and 1 for herbivores and detritivores); T is the mean annual habitat temperature for the fish population which is expressed as: 1000/ (Tc + 273.1), where Tc = average annual sea surface temperature (28.5°C) and A is the aspect ratio of the caudal fin, which is calculated by plotting the surface area of caudal fin on a graph paper as shown below.

Aspect ratio was calculated by the equation, $A=h^2/S$ (Sambilay, 1990), where, h is the height of the caudal fin and S is the surface area of caudal fin. This relationship was used only for fish groups that use their caudal fin as the main organ of propulsion. For the other ecological groups, appropriate empirical equations available in the Ecopath or information from literature were used.

Estimates of Biomass

The average biomass of each group per unit area in the habitat area (tonnes per km^2) was estimated. Biomass was estimated from the equation (of Gulland) B=Y/F, where Y is the annual average yield of each group and, F, the fishing mortality coefficient obtained from subtracting M from Z. For unexploited groups like phytoplankton, zooplankton, heterotrophic benthos and meiobenthos, biomass values estimated from the study area under other projects were used.

Group-wise Parameter Estimates

Diet composition and population parameter estimates of all species in each group are given in appendix. The composite diet matrix constructed out of the individual group averages and used as input in Ecopath is also given in appendix. Individual group descriptions are presented below. Group 1 to 23 are living groups and group 24, detritus is the only non-living group.

1. Marine mammals

The species occurring in this habitat area are the dolphins (*Stenella longirostris*, *Sousa chinensis*, *Delphinus delphis* and bottlenose dolphin, *Tursiops truncatus*). The diet of *T.truncatus* consisted of fishes, cuttlefish, *Acetes*, copepods and squilla. The Q/B estimate was taken from the published reports (Trites et al., 1999). The average biomass value was calculated as 0.019 tonnes per km^2. The annual average landing was 5 tonnes per km^2. These are not targeted and are incidental catches mainly in the GN fleet.

2. Sharks

Dominant shark species occurring along the Karnataka coast are *Rhizoprionodon acutus*, *Carcharhinus limbatus*, *Scoliodon laticaudus* and hammerhead shark, *Sphyrna lewini*. The major diet of *Carcharhinus limbatus* was oil sardine followed by a variety of fishes and cephalopods. The diet of all the sharks was pooled according to the ecological groupings to construct the diet matrix. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates are given in Table. The average biomass value of all sharks was estimated as 0.013 t per km^2. The annual average catch of sharks was 0.031 t per km^2.

Species	L_∞(cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Rhizoprionodon acutus	96	4226.3	2.16	1.61	7.15	
Carcharhinus limbatus	114	4001.2	4.81	2.40	8.41	
Scoliodon laticaudus	118	4965.0	2.50	1.05	6.22	
Sphyrna lewini	154	42577.0	3.63	1.26	4.18	
Mean	**121.0**	**13942.4**	**3.275**	**1.58**	**6.49**	**0.013**

3. Skates and Rays

The species occurring are *Rhinobatos granulatus*, *Rhinoptera javanica* and *Dasyatis* sp. The diet composition of *Manta birostris* was studied and the stomach contained exclusively of *Acetes* and few other crustaceans. The diet of *Dasytis* sp was threadfin breams and a variety of demersal fishes, *Acetes* and *Solenocera* sp. *Rhinobatos granulatus* feeds manly on crustaceans including *Acetes* and to some extent on fishes. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates of *Rhinobatos granulatus* are given in Table. The average biomass value was estimated as 0.022 t per km² as per the method described earlier. The annual average catch was 0.0097 tonnes per km².

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Rhinobatos granulatus	**97.8**	**4721.6**	**0.75**	**0.77**	**5.96**	**0.022**

4. Large Pelagics

Seerfish represented by *Scomberomorus commerson* and *S. guttaus*, kingfish (*Rachycentron canadum*) and barracudas (*Sphyraena obtusata* and *S. jello*) are the species, which constitute this group. Diet compositions of all these species were studied and the diets of all the fish groups were pooled according to the ecological groupings to construct the diet matrix. *S. commerson* feeds on a variety of fishes and to a lesser extent on crustaceans and cephalopods. The major food was anchovies. The major diets of *S. jello* as well as *S. obtusata* are also anchovies. The diet of *R. canadus* consists of a very large variety of fishes and crustaceans, which shows that there is no preference for any particular group. Asymptotic length, *P/B* estimates, Aspect ratio, *Q/B* estimates are given in the following Table. The average biomass value of all groups was 0.061 tonnes per km².

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Scomberomorus commerson	142.0	17088.1	5.33	4.74	9.78	
S. guttaus	69.0	2991.2	6.0	4.04	12.21	
Rachycentron canadum	180.0	37837.5	2.37	0.99	4.06	
Sphyraena obtusata	32.0	216.5	5.76	2.79	16.43	
S. jello	68.0	2336.6	1.88	2.62	9.79	
Mean	**98.4**	**12094.0**	**4.268**	**3.036**	**10.45**	**0.061**

5. Tunas

Dominant species are *Euthynnus affinis*, *Thunnus tonggol*, *Auxis thazard* and *Auxis rochii*. *E. affinis* prefers *Acetes* whereas for *Auxis thazard* and *A. rochei* fish is the favourite food. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates are given in the following Table. The average biomass was estimated as 0.032 t per km². The annual average catch was 0.114 tonnes per km².

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Auxis rochii	40	1128.9	4.72	4.94	17.70	
Euthynnus affinis	89	8745.2	4.95	5.94	14.11	
Auxis thazard	54	2932.4	3.74	5.11	15.05	
Thunnus tonggol	92	8195.3	6.70	7.23	18.29	
Mean	**68.9**	**5250.4**	**5.03**	**5.8**	**16.29**	**0.032**

6. Cephalopods

Dominant species are *Loligo duvaucelii*, *Sepia pharaonis and Sepia elliptica*. Published report on the diet of *Loligo duvaucelii* shows that fishes *Sardinella* sp, *Saurida* sp etc constitute the major diet followed by crustaceans. Asymptotic length, P/B estimates, Q/B estimates of all species under this group are given in Table. The Q/B estimate was taken from Amaratunga (1983) on the basis of 10% body weight ingestion per day. The average biomass values estimated were pooled and calculated as 0.234 tonnes per km^2. The annual average catch was 0.278 tonnes per km^2. The average *P/B* and *Q/B* values of cephalopods are 4.637 and 36.5.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Loligo duvaucelii	37.4	651.4	5.98			
Sepia pharonis	33.1	456.4	2.52			
Sepia eliptica	13.8	27.8	5.41			
Mean	**28.1**	**378.5**	**4.637**		**36.5**	**0.234**

7. Large Benthopelagics

Ribbonfish (*Trichiurus lepturus*), horse mackerel (*Megalaspis cordyla*), *Scomberoides tol*, wolf herring (*Chirocentrus dorab*) and catfish (*Tachysurus* sp) are represented in this group. Diet composition of all this species were studied in detail. The major diet of *Trichiurus lepturus* was anchovies followed by scads and *Acetes* sp. *C.dorab* prefers anchovies as their food. *M. cordyla* feeds on a different variety of fishes and anchovies dominated the diet. For *Tachysurus serratus* also the diet consisted of a wide variety of fish groups, crustaceans and cephalopods. The diet of all the fish groups was pooled according to the ecological groupings to construct the diet matrix. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates are given in the following Table. The average biomass values calculated were pooled and estimated as 0.106 t per km^2. The annual average catch was 0.351 t per km^2. The average *P/B* and *Q/B* values of large benthopelagics are 4.633 and 14.32 respectively.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Trichiurus lepturus	125.0	1285.5	4.68	0.01	6.72	
Megalaspis cordyla	53.4	1048.4	6.31	5.16	18.74	
Scomberoides tol	46.0	640.5	4.84	4.64	18.76	
Chirocentrus dorab	67.4	985.9	2.70	3.20	13.05	
Mean	**73.0**	**990.1**	**4.633**	**3.3**	**14.32**	**0.106**

8. Large Benthic Carnivores

The species dominant in this group are rock cod (*Epinephelus diacanthus*), *Pristipomoides filamentosus*, Lizardfish (*Saurida tumbil* and *S.undosquamis*). The diet of *E.diacanthus* consisted of a variety of fishes, crustaceans and cephalopods. The most dominant group is crabs forming 27% of the diet. Lizardfishes (*Saurida tumbil* and *S.undosquamis*) feed mainly on anchovies and squids beside a large variety of demersal fishes and some crustaceans. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates are given in the following Table. The pooled average biomass of large benthopelagics was estimated as 0.628 t per km^2. The annual average catch was 0.282 tonnes per km^2. The average *P/B* and *Q/B* values of large benthopelagics are 3.055 and 8.90. The diet of all the fish groups was pooled according to the ecological groupings to construct the diet matrix.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Epinephelus diacanthus	57.2	1541.8	4.16	1.22	8.16	
Pristipomoides filamentosus	70.0	7042.3	1.74	2.83	8.14	
Saurida tumbil	57.5	1608.5	3.70	1.32	8.24	
S. undosquamis	36.0	378.7	2.62	1.32	11.07	
Mean	**55.2**	**2642.8**	**3.055**	**1.70**	**8.90**	**0.628**

9. Medium Benthic Carnivores

A wide variety of fishes come under this ecological grouping. Among scianeids, *Johnieops sina* and *Otolithes cuvieri* are the dominant species. Squilla was the major food found in the stomach of *Johnieops sina* followed by *Acetes* and a large variety of planktonic crustaceans, polychaetes and foraminiferans. Other major fishes under this group are Flatheads (*Grammoplites suppositus*), Pomfret (*Pampus argenteus*), Black pomfret (*Parastromateus niger*) and Bull's eye (*Priacanthus hamrur*). The diet of *O. ruber* consisted of threadfin breams, oil sardine and anchovies and crustaceans. *P. niger* feed mainly on copepods (40%) and digested fish, squid and detritus also was found in good quantities. Other minor fish groups are threadfins (*Polynemus* sp), *Dactyloptera sp*, *Pseudorhombus arsius*, *P. natalensis* and Balistids. The diet of all the fish groups was pooled according to the ecological groupings to construct the diet matrix. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates of dominant fishes are given in the following Table. The annual average catch was 0.329 t per km^2. The average biomass was calculated as 0.108 t per km^2. The average *P/B* and *Q/B* values of pelagic predators are 4.88 and 16.42.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Grammoplites suppositus	31.5	205.5	4.62	3.53	19.13	
Johnieops sina	19.9	94.4	8.36	2.69	19.10	
Otolithes cuvieri	33.7	369.7	5.42	1.11	10.69	
Priacanthus hamrur	32.0	387.2	5.2	2.91	14.93	
Pseudorhombus arsius	35.0	443.3	3.63	1.14	10.36	
Pampus argenteus	33.0	685.6	4.21	2.58	31.2	
Parastromateus niger	62.7	3023.6	2.7	2.75	9.52	
Mean	**35.4**	**744.2**	**4.88**	**2.4**	**16.42**	**0.108**

10. Small Benthic Carnivores

Threadfin breams (*Nemipterus japonicus*, *N. mesoprion*), *Therapon* sp, whitefish (*Lactarius lactarius*), silverbellies (*Leioganthus bindus* and *Secutor insidiator*), are the dominant species in the group, while *Upeneus* sp, *Apogon* sp, *Uranscopus* sp and *Tetradon* also come under this group. The pooled average biomass value of the group was 0.530 tonnes per km^2. The annual average catch was 0.817 tonnes per km^2. The diet of *N. japonicus* consisted mainly of Squilla and crabs whereas *N. mesoprion* fed on *Acetes* and prawns. Anchovies and *Acetes* constituted the major food of *L. lactarius* besides other crustaceans and cephalopods as occasional food. Among silverbellies, the stomach of *Secutor insidiator* contained detritus, phytoplankton, diatoms and planktonic crustaceans. The diet of all the fish groups was pooled according to the ecological groupings to construct the diet matrix. The average *P/B* and *Q/B* values of small benthic carnivores are estimated as 5.268 and 0.530.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Nemipterus japonicus	32	394.7	5.04	2.12	12.79	
N. mesoprion	29	313.3	4.48	1.49	11.89	
Secutor insidiator	11.9	23.2	4.77	1.32	48.95	
Leioganthus bindus	13.26	31.4	6.27	2.13	53.7	
Lactarius lactarius	28.6	253.4	5.78	2.58	15.29	
Mean	**23.0**	**203.2**	**5.268**	**1.9**	**28.52**	**0.530**

11. Small Benthopelagics

Decapterus russelli, *D. macrosoma*, *Caranx kalla*, *Mene maculata* and Myctophids constituted this group. The diet of *D. russelli*, *D. macrosma* and *C. kalla* was studied. *Decapterus russelli* feed on fishes especially anchovies and crustaceans (*Acetes*). Food of *D. macrosoma* consisted of very few organisms like anchovies, digested fish and *Acetes*. *Caranx kalla* prefer *Acetes* but occasionally feed on small fishes. P/B estimates, Aspect ratio, Q/B estimates *C. kalla*, *D. russelli* and *D. macrosoma* are given below. The average biomass values of small benthopelagics were pooled and estimated as 0.281 tonnes per km^2. The annual average catch was 0.379 tonnes per km^2.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Decapterus russelli	23.18	127.6	2.7	2.46	2.46	
D. macrosoma	23.8	126.9	1.78	2.57	2.57	
Caranx kalla	16.8	137.7	2.67	2.70	2.70	
Mean	**21.3**	**130.7**	**2.38**	**2.6**	**2.6**	**0.281**

12. Mackerel

Rastrelliger kanagurta which is a major pelagic resource along Karnataka coast is caught by purse seine, trawl and indigenous gears. The diet of mackerel consisted of diatoms forming 88%, and dinoflagellates, bivalve larvae and zooplanktons (tintinnids, copepods, cladocerans) forming the rest. Asymptotic length was estimated as 30.1 cm. Aspect ratio, P/B estimates, Q/B estimates are given in Table. The average biomass of mackerel in Karnataka waters is estimated as 0.249 tonnes per km^2. The annual average catch was 0.945 tonnes per km^2.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Rastrelliger kanagurta	**30.16**	**333.7**	**6.24**	**3.82**	**62.36**	**0.249**

13. Clupeids

Oil sardine, *Sardinella longiceps* that is abundant in Karnataka waters, lesser sardines (*Sardinella fimbriata*, *S. gibbosa)*, *Thryssa mystax*, *Dussumieria acuta*, *Esculosa thoracata* are the major species under this group. Besides *Pellona* sp and *Opisthopterus tardoore* are the other clupeid species included in this group. The major food items of *S. longiceps* were diatoms and copepods, which together formed 68% of the diet. Copepods alone constituted 63% of the food item of *S.gibbosa* followed by diatoms. *Thryssa mystax* feeds on a wide variety of organisms including *Bregmaceros*, young ones of sciaenids and serranids, shrimps, diatoms and crustaceans. The principal diet of *Dussumieria acuta* was anchovies while juvenile fishes, crustaceans and diatoms were found in the stomach. Copepods formed 40% of the diet of *Esculsosa thoracata* and other groups found were larval forms of crustaceans, Diatoms and zooplanktons. Asymptotic length, Asymptotic weight, P/B estimates, Aspect ratio, Q/B estimates of the major species are given in the following Table. The pooled average biomass value of clupeids along Karnataka waters was estimated as 0.289 tonnes per km^2. The annual average catch was 1.44 tonnes per km^2.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km^2)
Sardinella longiceps	23.3	94.1	6.36	2.96	68.49	
Thryssa mystax	22.7	88.6	5.77	1.57	15.62	
Sardinella gibbosa	21.1	83.1	6.88	2.41	63.25	
Sardinella fimbriata	21.7	74.8	6.11	1.18	14.99	
Dussumieria acuta	23.4	96.4	2.26	2.47	18.24	
Esculosa thoracata	13.9	28.4	7.02	2.20	55.55	
Mean	**21.0**	**77.6**	**5.79**	**2.1**	**39.56**	**0.289**

14. Anchovies

Stolephorus devisi, *S. batavensis*, *S. commerson*, *S. indicus* and the unicorn cod *Bregmaceros mclellandi* are included in this group. These group forms the major food of many fishes higher in the trophic level. *Stolephorus devisi* feeds on copepods, diatoms, planktonic crustaceans. Whereas *S. waitei* and *S. commerson* feeds mainly on mysis, *S. indicus* feeds mainly on young ones of flatfish and mysis. The diets of all the fish groups were pooled according to the ecological groupings to construct the diet matrix. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates of *S. devisi*, *S. bataviensis* and *S. buccaneeri* are provided in the following Table. The average biomass values of all species were pooled and estimated as 0.110 tonnes per km^2. The annual average catch was 0.201 tonnes per km^2.

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Stolephorus devisi	10.35	6.8	4.13	1.11	82.16	
S. batavensis	13.0	14.4	5.67	1.09	20.65	
S. buccaneri	11.7	10.7	4.06	1.81	25.18	
Mean	**11.7**	**10.6**	**4.62**	**1.3**	**42.66**	**0.110**

15. Crabs and Lobsters

Portunus sanguinolentus, P. pelagicus, Charybdis cruciata and Panulirus sp are included in this group. Diet composition, asymptotic length, P/B estimates of *P. sanguinolentus* and *P. pelagicus* was made and provided in the following table. The Q/B value was taken from literature (Manickchand-Heileman et al., 1998). Crustaceans formed 55 and 47% of the diet of these species respectively followed by fish, molluscs, polychaetes and detritus. The pooled average biomass value of crabs and lobsters was estimated as 0.140 tonnes per km². The annual average catch was 0.351 tonnes per km². The annual average catch was 0.061 tonnes per km².

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Portunus pelagicus	20.75	874.4	6.63		–	
P. sanguinolentus	19.15	418.2	6.20		–	
Mean	**20.0**	**646.3**	**6.41**		**8.50**	**0.140**

16. Shrimps

Metapenaeus monoceros, *M. dobsoni*, *P. stylifera*, *Solenocera choprai*, *Trachypenaeus* sp, *Aristeus* sp and *Acetes* are the species coming under this group. Diet composition of *M. monoceros* indicated preference for crustaceans besides a wide variety of organisms ranging from polychaetes, formainiferans, diatoms and fish. Asymptotic length, of *M. monoceros* and *Acetes indicus* was taken from published reports (Sukumaran et al., 1993). The average *P/B* was estimated as 6.68. The average biomass values were pooled and estimated as 0.826 tonnes per km². The annual average catch was 0.306 tonnes per km²

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Metapenaeus monoceros	19.5	60.0	7.97	–	19.20	
Acetes indicus	4.0		5.39			
Mean	**11.8**		**6.68**		**19.20**	**0.826**

17. Benthic Omnivores

Malabar sole, *Cynoglossus macrostomus*, Catfish eel (*Plotosus* sp), *Fistularia* sp and the mantis shrimp *Oratosquilla nepa* constituted this group. Diet composition studies of *C. macrostomus* and *O. nepa* were carried out. *C. macrostomus* is a detritus feeder and other food items found in the stomach are molluscan shells, diatoms, planktonic crustaceans, polychaetes and crustaceans. *O. nepa* feeds on detritus, crustaceans, gastropods and diatoms. Asymptotic length, P/B estimates, Aspect ratio, Q/B estimates are given in the following Table. The pooled average biomass value was estimated as 0.556 tonnes per km². The annual average catch was 0.844 tonnes per km².

Species	L_∞ (cm)	W_∞ (g)	P/B	Aspect ratio	Q/B	Biomass (t/km²)
Cynoglossus macrostomus	17.5	27.1	7.74	0.01	36.91	
Oratosquilla nepa	12.10	18.0	5.27	–	19.2	
Mean	**14.8**	**22.5**	**6.05**	**0.01**	**28.06**	**0.556**

18. Heterotrophic benthos

This group includes the benthic epifauna represented by bivalves, gastropods, echinoderms, benthic crabs, amphipods and isopods. The average biomass of heterotrophic benthos was estimated based on the Van Veen Grab sampling (0.1 m^2) carried out at different depths in connection with a DOD funded research project on effect of bottom trawling on benthic fauna. The average biomass of this component was estimated as 38.0 tonnes per km^2.

19. Meiobenthos

Meiobenthos includes benthic infauna comprising annelid worms, polychaete worms, foraminiferans and hydrozoans. The average biomass value was estimated as 20.0 tonnes per km^2 by the method mentioned above.

20. Nekton

Jellyfish, Leptocephalus larvae of eels and juveniles of all fishes are included in this group. The average biomass value was calculated from the report of Menon (1990) as 0.008 tonnes per km^2.

21. Large Zooplankton

The dominant members of this group are Alima larva, *Cypris*, *Calanus* sp, Zoea of crab, Megalopa, Cladocerans, Sagitta, Mysids, Lucifer larva, Medusa and Siphonophores. The average biomass values estimated were pooled and estimated as 4.0 tonnes per km^2 from the monthly zooplankton average biomass estimates made in institute research project.

22. Micro Zooplankton

Fish eggs, decapod eggs and larvae, bivalve larvae and tintinnids are included. The average biomass of micro-zooplankton was taken as 10.0 tonnes per km^2 as described for group 21.

23. Phytoplankton

Fragillaria, *Coscinodiscus*, *Thalassiothrix*, *Pleurosigma*, *Flavella*, *Asterionella*, *Rhizosolenia*, *Chaetoceros*, *Nitzchia*, *Noctiluca* and *Ceratium* are the common phytoplankton species occurring in the Arabian Sea ecosystem of Karnataka. The average biomass was taken as 45 tonnes per km^2 based on the published model from similar latitude in Venezuela (Mendoza, 1993).

24. Detritus

The energy, which is not used within the system (i.e. the part of the production of each group that is not consumed within the system = 1-EE), is automatically destined to the detritus compartment by Ecopath. For the present analysis however, the estimate of detritus biomass was made by using Pauly's [1993] empirical equation,

$$Log\ D = 0.954\ log\ PP + 0.863\ log\ E - 2.41$$

where D is the detrital biomass (g C per m^2), PP is the primary production (taken as 100 mgC m^{-2} $year^{-1}$ from Longhurst et al. (1995) and E is the euphotic layer depth (taken here as 50 m). By converting 1 gC equal to 10 g wet weight of detritus [Christensen and Pauly, 1992], the detritus biomass was estimated as 9.3 tonnes per km^2.

Data Pedigree and Pedigree Index

The pedigree of an Ecopath input is a coded statement categorizing the origin of a given input (i.e., the type of data on which it is based), and by the same token, specifying the likely uncertainly associated with the input.

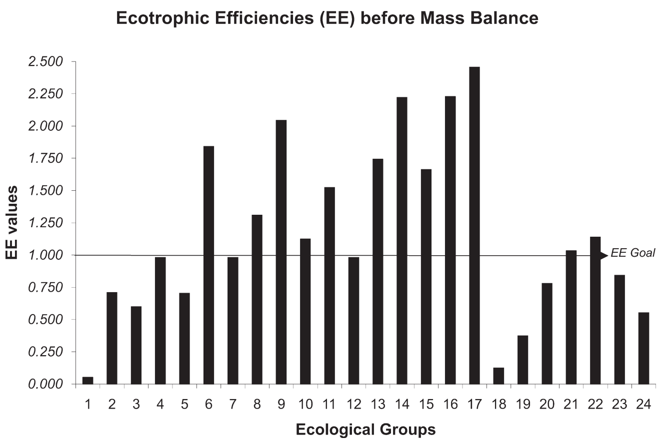
The key criterion used here is that input estimated from local data (i.e., from the area covered by the model is question) as a rule is better than the data from elsewhere, be it a guesstimate, derived from empirical relationships or derived from other Ecopath models. These requirements are met here by three scales, one for biomass, one for P/B and Q/B estimates, and one for diet composition.

The pedigree index values are used to calculate an overall pedigree index for a given model. The index values for input data scale from 0 for data that is not rooted in local data up to a value of 1 for data that are fully rooted in local data. The measure of fit (t*) is also calculated to describe how well rooted a given model is in local data.

PARAMETER	PEDIGREE FIXED	INDEX	DEFAULT CI (+/-%)
Biomass	Approximate or indirect method	0.4	60
P/B	Same group/species, same system	1.0	10
Q/B	Empirical relationship	0.5	50
Diets	Quantitative but limited diet composition study	0.7	40
Catches	National statistics	0.5	40
Ecopath Pedigree Index		**0.521**	
Measure of fit (t*)		**2.79**	

Ecopath Runs for Achieving Mass Balance

All input parameters (biomass, P/B and Q/B ratios, diet matrix and fleet-wise fishery information) were entered in the basic inputs sheet of the software. Since the model was designed to represent an average for one year, biomass accumulation was taken as zero. The software using mass balance routine estimated the P/Q ratio and EE. On initial run, 12 of the 24 groups had an estimated EE above 1 (see figure below).



Ecotrophic efficiencies above 1.0 indicate that demands on those groups are too high to be sustainable. For such groups adjustments were made in their biomasses. For example for group 6, the biomass was increased from 0.117 t/km^{-2} to 0.234 t.km^{-2}. Similarly, group 8 biomass was increased from 0.157 to 0.628; group 10 from 0.265 to 0.53; group 14 from 0.11 to 1.11; group 15 from 0.014 to 0.14; group 16 from 0.118 to 0.826; group 17 from 0.278 from 0.556; group 20 from 0.008 to 0.80 and group 23 from 45 to 58.5.

Thereafter, the auto mass balance routine of the software was run. The procedures outlined by Kavanagh (2002) were followed. Auto mass balance defaults were chosen with the following selections. Neighbourhood perturbation was made at a level of 6% of the original value. Random gaussian noise at 6% was introduced and allowance was made for change in biomass and diets in order to reduce zero-order cycles or cannibalism. Each run was made with 10,000 iterations. After 3 runs, with each new run continuing with biomass and diet composition values of the previous run, mass balance was achieved. Maximum biomass and diet changes were made for group 5 (tunas) and group 19 (meiobenthos). The basic inputs obtained after mass balance and modified diet composition is shown in table.

Table. Basic estimates obtained after mass-balancing using auto-mass balance routine of ECOPATH

Group No	Group name	Trophic level	Habitat area	Biomass in habitat area (t/km²)	P/B (/year)	Q/B (/year)	EE	P/Q
1	Marine Mammals	4.06	1	0.019	0.200	12.750	0.051	0.016
2	Sharks	4.45	1	0.013	3.275	8.500	0.709	0.385
3	Skates & Rays	3.59	1	0.022	0.750	5.960	0.599	0.126
4	Large Pelagics	4.18	1	0.061	4.268	10.450	0.980	0.408
5	Tunas	4.14	1	0.032	5.028	16.290	0.703	0.309
6	Cephalopods	4.18	1	0.234	4.637	36.500	0.975	0.127
7	Large Benthopelagics	4.15	1	0.106	4.633	14.320	0.980	0.324
8	Large Benthic Carnivores	4.14	1	0.628	3.055	8.900	0.980	0.343
9	Medium Benthic Carnivores	3.19	1	0.108	4.877	16.420	0.981	0.297
10	Small Benthic Carnivores	2.68	1	0.530	5.268	28.520	0.979	0.185
11	Small Benthopelagics	3.88	1	0.281	2.383	17.490	0.978	0.136
12	Mackerel	2.00	1	0.249	6.240	62.360	0.980	0.100
13	Clupeids	2.95	1	0.289	7.465	39.360	0.979	0.190
14	Anchovies	3.49	1	1.110	4.620	42.660	0.977	0.108
15	Crabs & Lobster	2.89	1	0.140	6.415	14.500	0.976	0.442
16	Shrimps	3.02	1	0.826	6.680	19.200	0.980	0.348
17	Benthic Omnivores	2.55	1	0.556	6.505	28.060	0.980	0.232
18	Heterotrophic Benthos	2.32	1	38.000	3.000	12.500	0.124	0.240
19	Meiobenthos	2.02	1	20.000	12.500	40.000	0.373	0.313
20	Micro Nekton	3.24	1	0.800	20.000	125.000	0.778	0.160
21	Large Zooplankton	2.58	1	4.000	35.000	225.000	0.980	0.156
22	Micro Zooplankton	2.00	1	10.000	60.000	300.000	0.980	0.200
23	Phytoplankton	1.00	1	58.500	70.000	-	0.842	-
24	Detritus	1.00	1	9.300	-	-	0.552	-

Results of Karnataka Ecopath Model

The resource biomass structure of the Arabian Sea ecosystem model of Karnataka indicates that it is primarily a low trophic level driven ecosystem. The summary statistics of the system is given in Table below.

Table. System statistics - Karnataka Arabian Sea Trophic Model

Parameter	Value	Units
Sum of all consumption	5421	t/km²/year
Sum of all exports	904	t/km²/year
Sum of all respiratory flows	3190	t/km²/year
Sum of all flows into detritus	2005	t/km²/year
Total system throughput	11522	t/km²/year
Sum of all production	5243	t/km²/year
Mean trophic level of the catch	3.04	
Gross efficiency (catch/net p.p.)	0.001605	
Calculated total net primary production	4095	t/km²/year
Total primary production/total respiration	1.283	
Net system production	904	t/km²/year
Total primary production/total biomass	29.999	
Total biomass/total throughput	0.012	
Total biomass (excluding detritus)	136	t/km²
Total catches	6.57	t/km²/year
Connectance Index	0.382	
System Omnivory Index	0.299	

Total system throughput

Total system throughput is the sum of all flows in a system, expressed, e.g., in t/km^2/year. Total system throughput represents the 'size of the entire system in terms of flow' (Ulanowicz 1986). As such, it is an important parameter for comparisons of flow networks. It is estimated as the sum of four components of the flows, i.e., Total consumption + Total export + Total respiration + Total flows to detritus = Total system throughput. The total system throughput estimated for Arabian Sea ecosystem of Karnataka was 11,522 t/km^2/year, which is comparatively high, but is consistent with tropical marine ecosystems with high turnover.

Mean trophic level of the catch

This functions as an important index of the overall level of exploitation of fish groups low in the food web and its effect on predator and prey species. Fishing down the marine food web, wherein fishing fleets increasingly target species low in the food web, may or may not be the cause for decline in global mean trophic levels of catches. The fishery in the Arabian Sea ecosystem of Karnataka had a mean trophic level of 3.04, with the minimum being 1 (phytoplankton) and maximum 4.45 (sharks).

Gross efficiency of the fishery

This is computed as the ratio between the total catch (landings plus discards) and the total primary production in the system. This ratio will vary widely between different systems. Value will be higher for systems with a fishery harvesting fish low in the food chain (e.g., an upwelling fishery) than for systems whose fisheries concentrate on apex predators (e.g., oceanic tuna fisheries). Hence, the index may increase with fisheries 'development'. The index is the ratio between two flows, and is thus dimensionless. It is generally much lower than 1.0 (the weighted global average is about 0.0002). For the Karnataka model the value obtained was 0.0016 indicating a fishery harvesting fishes low in the food chain. The Arabian Sea ecosystem of Karnataka is well known as being part of the Malabar upwelling system where lower trophic level pelagic fishes dominate.

Total primary production / total respiration

This ratio is considered by Odum (1971) to be an important ratio for description of the 'maturity' of an ecosystem. In the early developmental stages of a system, production is expected to exceed respiration, leading to a ratio greater than 1. In systems suffering from organic pollution, this ratio is expected to be less than 1. Finally, in 'mature' systems, the PP/R ratio should approach 1; the energy that is fixed is approximately balanced by the cost of maintenance. The ratio can take any positive value and is dimensionless. According to Odum's classification the Arabian Sea ecosystem of Karnataka is in a developing stage with ratio being greater than 1 (1.283).

Net system production

Net system production (or yield) is the difference between total primary production and total respiration. System production will be large in immature systems and close to zero in mature ones. Systems with large imports may have a negative system production. Systems production has the same unit as the flows from which it is computed, e.g., t/km² /year. The value of 904 t/km² /year obtained for Arabian Sea ecosystem of Karnataka again indicates the developing nature of the ecosystem.

Total primary production / total biomass

The ratio between a system's primary production and its total biomass (B) is expected to be a function of its maturity. In immature systems, production exceeds respiration, and as a consequence, one can expect biomass to accumulate over time. This, in turn, will influence the system PP/B ratio, which may decrease. The system PP/R ratio behaves like that of individual groups; its dimension is per unit time, and it can take any positive value, and in the present instance it was 29.99.

Total biomass / total throughput

The total system biomass that is supported by the available energy flow in a system can be expected to increase to a maximum for the maturest stages of a system (Odum 1971). For the estimation of this ratio, total system throughput is used as a measure consistent with other Ecopath outputs; (E.P. Odum used the sum of total primary production and total system respiration). The system biomass / throughput ratio can take any positive value (0.012 for Arabian Sea ecosystem of Karnataka), and has time as dimension.

Total system biomass and total catches

These variables are simply the sums of the group biomasses excluding detritus of the harvests. They have the same unit as the group biomasses and catches, e.g., t/km², and t/km² /year, respectively. The production of a group in a system is size-specific, and it has been demonstrated that the inverse of a group's production / biomass ratio is a measure of size (see, e.g., Christensen and Pauly, 1993). This, presumably, is also the case on a system level, and this enables the use of the ratio between total biomass and total production as an index of the average size of the organisms in a system.

Connectance index

The connectance index (CI) is for a given food web, the ratio of the number of actual links to the number of possible links. Feeding on detritus (by detritivores) is included in the count, but the opposite links (i.e., detritus 'feeding' on other groups) are disregarded. The number of possible links in an Ecopath model can be estimated as $(N-1)^2$. It has been observed that the actual number of links in a food web is roughly proportional to the number of groups in the system (Nee, 1990). Hence, the connectance index can be expected to be correlated with maturity. The value of the connectance index is - at least in aquatic systems - largely determined by the level of taxonomic detail used to represent prey groups, and this preclude meaningful intersystem comparisons. The system omnivory index is suggested as an alternative.

System omnivory index

System omnivory index is defined as the average omnivory index of all consumers weighted by the logarithm of each consumer's food intake (recall that the latter is estimated as biomass times the consumption / biomass ratio). The logarithms are used as weighting factors because it can be expected that the intake rates are approximately log normally distributed.

The system omnivory index is a measure of how the feeding interactions are distributed between trophic levels. The system omnivory index was inspired by perceived drawbacks of the connectance index. The connectance index is strongly dependent on how the groups of the system are defined. As this is quite arbitrary in aquatic systems, where interactions of nearly all groups are possible at some development stage, connectance would be close to 1 in most systems described. Moreover, a prey has the same 'score' in the connectance index whether it contributes 1, 10 or 100% of its predators' diet. Both of these drawbacks are overcome by the system omnivory index. For the Arabian Sea ecosystem of Karnataka an index value of 0.299 was obtained.

Key Indices and Mortalities

Under equilibrium, each group can be represented by an average organism, with an average weight. This makes it possible to use equations for estimating mortality in numbers, even when dealing with biomass. One such equation is

$$N_t = N_0 \cdot e^{-zt}$$

where: N(0) is the number of organism at time = 0; N(t) is the number of survivors at time = t; and Z is the instantaneous rate of mortality. Under the assumption that Z(i), the mortality of group i, is constant for the organisms included in i, it turns out that, for a large number of growth functions (including the von Bertalanffy Growth Function, or VBGF):

$$Z_i = (production\ /\ biomass)_i = P\ /\ B_i$$

or the instantaneous mortality equals total production over mean biomass (Allen, 1971). The mortality coefficient can be split into its components following a procedure well known among fisheries biologists, i.e.,

Total mortality = other mortality + predation mortality + catch + other exports

or expressed as a series of instantaneous rates for a group i

$$Z = P/B = F + M2 + BA/B + E + M0$$

Where the group index i for all groups is omitted. Here, P/B is production/biomass rate, F the fishing mortality rate (F = C/B, where C is the catch and B the biomass), M2 the predation mortality rate, BA/B the biomass accumulation over biomass rate, E the migration rate, and M0 the 'other mortality' rate. In some models, (e.g., the Multispecies VPA model of the North Sea), this component is split between form for instantaneous mortality rates, e.g., M2, the predation asserted by predators not included in the model, and M1, 'other mortality', caused by diseases, senescence, etc. In Ecopath, M1 is not included, as this kind of predation mortality should be treated as an export (included in E). Further, M0 is not entered directly, but is computed from the ecotrophic efficiency, EE. The migration rate E is the coefficient for other exports, and represents the part of the mortality that is attributed to exports other than catches, e.g., emigration out of the system, or food intake of predators that are not part of the system.

If any component of the system is harvested, a summary of the mortality coefficients can be displayed, which presents total mortality (Z = P/B) and its components. Predation mortality is further broken down on a separate table to show the contribution of each consumer groups to the total predation mortality of each prey group.

Table: Estimated group-wise split mortality rates of different ecological groups

Group No.	Group name	Prod./biom rate = Z	Fishing mort. rate = F	Predat.mort. Rate=M2	Other mort. Rate=M0
1	Marine Mammals	0.200	0.010	0.000	0.190
2	Sharks	3.275	2.321	0.000	0.954
3	Skates & Rays	0.750	0.450	0.000	0.300
4	Large Pelagics	4.268	3.016	1.166	0.086
5	Tunas	5.028	3.533	0.000	1.495
6	Cephalopods	4.637	1.189	3.332	0.115
7	Large Benthopelagics	4.633	3.313	1.226	0.094
8	Large Benthic Carnivores	3.055	0.449	2.544	0.062
9	Medium Benthic Carnivores	4.877	3.037	1.745	0.095
10	Small Benthic Carnivores	5.268	1.541	3.615	0.112
11	Small Benthopelagics	2.383	1.347	0.983	0.053
12	Mackerel	6.240	3.800	2.315	0.125
13	Clupeids	7.465	4.975	2.333	0.158
14	Anchovies	4.620	0.181	4.334	0.105
15	Crabs & Lobster	6.415	0.436	5.825	0.154
16	Shrimps	6.680	0.369	6.175	0.137
17	Benthic Omnivores	6.505	1.519	4.855	0.131
18	Heterotrophic Benthos	3.000	0.000	0.372	2.628
19	Meiobenthos	12.500	0.000	4.666	7.834
20	Micro Nekton	20.000	0.000	15.564	4.436
21	Large Zooplankton	35.000	0.000	34.299	0.701
22	Micro Zooplankton	60.000	0.000	58.800	1.200
23	Phytoplankton	70.000	0.000	58.964	11.036

The predation mortality rates were considerably higher than fishing mortality rate among the commercially exploited groups with respect to cephalopods (Grp 6), large benthic carnivores (Grp 8), small benthic carnivores (Grp 10), anchovies (Grp 14), crabs and lobsters (Grp 15), shrimps (Grp 16) and benthic omnivores (Grp 17). This indicates the predation pressure exerted on these groups by other groups. The top 3 apex predator groups and tunas had no predatory pressure. The group-wise predation mortality rates is given in Appendix.

The key indices of the Arabian Sea ecosystem of Karnataka are shown in table below. It was assumed that there was no biomass accumulation (since the model is an average for the period 1999-2001) and no migration from the system.

The flows to detritus was maximum for phytoplankton and micro zooplankton followed by meiobenthos and heterotrophic benthos. The least flows were observed for apex predators. For each group, the flow to the detritus consists of what is egested (the non-assimilated food) and those elements of the group that die of old age, diseases, etc. (sources of 'other mortality' or 1-EE).

The net food conversion efficiency is calculated as the production divided by the assimilated part of the food,

$$\text{Net efficiency} = P/B \,/\, (Q/B\ (1\text{-}GS))$$

where P/B is the production/biomass ratio, Q/B is the consumption/biomass ratio, and GS is the proportion of the food that is not assimilated.

The net efficiency is a dimensionless fraction. It is positive and, in nearly all cases, less than 1, the exceptions being groups with intermediate trophic modes, e.g. groups with symbiotic algae. The net efficiency cannot be lower than the gross food conversion efficiency, i.e. the ratio between production and consumption.

The 'omnivory index' was introduced in 1987 (see Pauly et al. 1993), in the initial version of the Ecopath software. This

Table. Key indices of the ECOPATH model of Arabian Sea off Karnataka

Group No.	Group name	± Biom.acc. (t/km²/year)	Net migration (t/km²/year)	Flow to detr. (t/km²/year)	Net efficiency	Omnivory index
1	Marine Mammals	0	0	0.051	0.020	0.250
2	Sharks	0	0	0.035	0.482	0.513
3	Skates & Rays	0	0	0.032	0.157	0.552
4	Large Pelagics	0	0	0.134	0.511	0.652
5	Tunas	0	0	0.153	0.386	0.088
6	Cephalopods	0	0	1.735	0.159	0.313
7	Large Benthopelagics	0	0	0.313	0.404	0.564
8	Large Benthic Carnivores	0	0	1.157	0.429	0.208
9	Med Benthic Carnivores	0	0	0.366	0.371	0.835
10	Small Benthic Carnivores	0	0	3.082	0.231	0.650
11	Small Benthopelagics	0	0	0.999	0.170	0.579
12	Mackerel	0	0	3.134	0.125	0.000
13	Clupeids	0	0	2.324	0.237	0.694
14	Anchovies	0	0	9.587	0.135	0.200
15	Crabs & Lobster	0	0	0.428	0.553	0.313
16	Shrimps	0	0	3.285	0.435	0.502
17	Benthic Omnivores	0	0	3.193	0.290	0.379
18	Heterotrophic Benthos	0	0	194.879	0.300	0.296
19	Meiobenthos	0	0	316.678	0.391	0.023
20	Micro Nekton	0	0	23.549	0.200	0.280
21	Large Zooplankton	0	0	182.802	0.194	0.243
22	Micro Zooplankton	0	0	612.004	0.250	0.000
23	Phytoplankton	0	0	645.597	-	0.000
24	Detritus	0	0	0.000	-	0.366

index (OI) is calculated as the variance of the trophic level of a consumer's prey groups. When the value of the omnivory index is zero, the consumer in question is specialized, i.e., it feeds on a single trophic level. A large value indicates that the consumer feeds on many trophic levels. The omnivory index is dimensionless. The maximum OI was observed for Group 9 medium benthic carnivores, followed by Group 10 clupeids and Group 4 large pelagics. Highly specialized feeding was observed for tunas and mackerel.

Consumption

The food intakes for all groups are given in Appendix. The food intake of a group is the product of its biomass (B) times its consumption/biomass ratio (Q/B). The food intake is a flow rate expressed using t / km² / year as unit. Higher consumption was estimated for groups in the lower trophic levels. Maximum was observed for micro-zooplankton (3000 t / km² / year).

Respiration and Assimilation

Respiration includes all non-usable 'model currency' that leaves the box representing a box. In Ecopath the respiration is used only to balance the flows between groups using the Second Master Equation, Consumption = production + respiration + unassimilated food. Respiration is a non-negative flow expressed in t/km²/year.

Assimilation: The part of the food intake that is assimilated is computed for each consumer group (i) from B · Q/B · (1 – GS). Here, (omitting group i indices throughout) B is the biomass of group i; Q/B is the consumption/ biomass ratio of group i; and GS is the part of the consumption that is not assimilated (but excreted or egested). Assimilation is a flow expressed in t/km²/year.

The estimates of respiratory flows and respiration assimilation ratios for the Karnataka ecosystem are given in table below.

Respiration/assimilation: This (dimensionless) ratio cannot exceed 1 as respiration cannot exceed assimilation. For top predators, whose production is relatively low, the respiration/ assimilation ratio can be expected to be close to 1, while it will tend to be lower for organisms at lower trophic levels. This was clear from the very high respiration assimilation ratio obtained for marine mammals.

Table. Estimates of respiratory flows and respiration assimilation and production respiration ratios. Respiration is a non-negative flow expressed as t/km²/year

Group No.	Group name	Respiration (t/km²/year)	Assimilation (t/km²/year)	Respiration/ Assimilation	Production/ respiration	Respiration/ biomass (/year)
1	Marine Mammals	0.185	0.189	0.980	0.020	10.000
2	Sharks	0.047	0.090	0.518	0.929	3.525
3	Skates & Rays	0.087	0.104	0.843	0.187	4.018
4	Large Pelagics	0.251	0.513	0.489	1.043	4.092
5	Tunas	0.258	0.420	0.614	0.628	8.004
6	Cephalopods	5.748	6.833	0.841	0.189	24.563
7	Large Benthopelagics	0.723	1.214	0.596	0.679	6.823
8	Large Benthic Carnivores	2.553	4.471	0.571	0.752	4.065
9	Medium Benthic Carnivores	0.895	1.424	0.629	0.591	8.259
10	Small Benthic Carnivores	9.300	12.092	0.769	0.300	17.548
11	Small Benthopelagics	3.268	3.938	0.830	0.205	11.609
12	Mackerel	10.859	12.412	0.875	0.143	43.648
13	Clupeids	6.954	9.115	0.763	0.311	24.023
14	Anchovies	32.754	37.882	0.865	0.157	29.508
15	Crabs & Lobster	0.726	1.624	0.447	1.237	5.185
16	Shrimps	7.170	12.687	0.565	0.770	8.680
17	Benthic Omnivores	8.864	12.481	0.710	0.408	15.943
18	Heterotrophic Benthos	266.000	380.000	0.700	0.429	7.000
19	Meiobenthos	390.000	640.000	0.609	0.641	19.500
20	Micro Nekton	64.000	80.000	0.800	0.250	80.000
21	Large Zooplankton	580.000	720.000	0.806	0.241	145.000
22	Micro Zooplankton	1800.000	2400.000	0.750	0.333	180.000
23	Phytoplankton	0.000	-	-	-	-
24	Detritus	0.000	-	-	-	-

Production/respiration: The (dimensionless) ratio expresses the fate of the assimilated food. Computationally, this ratio can take any positive value, though thermodynamic constraints limit the realized range of this ratio to values lower than 1.

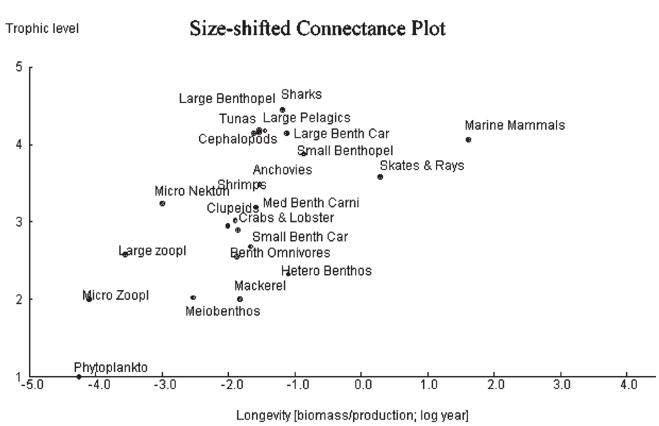
Respiration/biomass: The ratio can take any positive value, and has the dimension per unit time. It can be a useful when balancing a model.

Niche Overlap

Numerous overlap indices have been suggested for quantification of how species overlap. Hurlbert (1978) and Loman (1986) summarized different types of indices, and described their properties based on a number of hypothetical examples. One presents the overlap between food types (Prey overlap), and another the overlap between predators (Predator overlap). The indices scales from 0 (no overlap) to 1 (identical diet or predator compositions). A modification of the Pianka (1973) overlap index derived from the competition coefficients of the Lotka-Volterra equations are used in Ecopath.

Overlap indices can be used as tools for generation of hypotheses. Another area where niche indices may be useful is in the aggregation process. Aggregation is an important area of model construction. Often-stated criterions for optimal aggregation is that one should aggregate ecologically related groups, rather than groups that are only taxonomically related. A major criterion used for such aggregation has been diet composition, but by only including feeding aspects, and overlooking predator composition, leads to valuable information not being utilized. Aggregation can more sensibly be conducted by using both food and predator compositions, for instance by calculating both of the overlap indices described above and then aggregating the groups that show most overlap.

The prey and predator niche overlaps for the Arabian Sea ecosystem of Karnataka is given in table in appendix. The prey overlap table indicates that tunas, cephalopods and large benthic carnivores have significant overlap in their diets with marine mammals. Maximum prey overlaps were observed for group 9, medium benthic carnivores. Similarly, large pelagics and large benthopelagics had significant predator overlaps. Maximum predatory overlap was observed in the case of cephalopods. A graphical representation of the overlap indices based on size is depicted below as size shifted connectance plot.



Electivity

The selection indices or electivity describe a predator's preference for prey. It scales from -1 to 1; where -1 indicates total avoidance of a prey; 0 indicates that a prey is taken in proportion to its abundance in the ecosystem; and 1 indicates total preference for a prey. The electivity index used is the standardized forage ration of Chesson (1983). One of the most widely used indices for selection is the Ivlev electivity index, Ei (Ivlev 1961) defined for a group (i) as:

$$Ei = (ri - Pi) / (ri + Pi)$$

where ri is the relative abundance of a prey in a predator's diet and Pi is the prey's relative abundance in the ecosystem. Ei is scaled so that Ei = -1 corresponds to total avoidance of, Ei = 0 represents non-selective feeding on, and Ei = 1 shows exclusive feeding on a given prey i. As implemented in Ecopath the forage ratio of Chesson (1983) has been transformed (linearly) such as to vary between -1 and 1, so that -1, 0 and 1 can be interpreted as for the Ivlev index.

In the Arabian Sea ecosystem of Karnataka, each group's preference for preys is shown in table in appendix. Sharks had a marked preference for large pelagics, while it avoided small benthic carnivores and small benthopelagics. Group 9 medium benthic were very selective feeders (on benthic omnivores and large zooplankton) avoiding most prey groups.

Search Rates

The Ecopath approach can be used to estimate the Lotka-Volterra mass-action term 'a', which has the dimension of a volume searched per unit time by a given predator *j* seeking a certain prey *i*. This mass-action term is used as 'fixed support' for the 'lever', which, in Ecosim, regulates the consumption of predators, given the changing biomasses of their preys, and their own changing biomasses.

The values of 'a' depend obviously on the units used, and the biomass units used in Ecopath render difficult a direct interpretation of the numbers in the 'Search rate' table. However, they can easily be converted into values of 'a' applying to single organisms, given that the ratio of the individual prey and predator weights are divided into the values of 'a' for each pair of prey and predator. The search rates for groups of the Arabian Sea ecosystem of Karnataka is shown in table in appendix. Higher trophic level groups showed higher search rates than lower trophic level groups.

Network Analysis

Cycling Index

The 'cycling index' is the fraction of an ecosystem's throughput that is recycled. This index, developed by Finn (1976), is expressed here as percentage. It was originally intended to quantify one of Odum's (1969) 24 properties of system maturity. However, its interpretation is apparently not as simple as originally conceived, with an increase of recycling as a system matures. Wulff and Ulanowicz (1989) suggest that the opposite may indeed be the case. One added problem is that this index varies with the 'currency' used: nutrients are recycled more strongly than energy-related indices (such as weight).

In addition to Finn's cycling index, Ecopath includes a slightly modified 'predatory cycling index', computed after cycles involving detritus groups have been removed.

Table. Cycling and path length- Karnataka Arabian Sea

Parameter	Value	
Throughput cycled (excluding detritus)	28.41	t/km²/year
Predatory cycling index	0.38	% of throughput w/o detritus
Throughput cycled (including detritus)	4.09	t/km²/year
Finn's cycling index	6.03	% of total throughput
Finn's mean path length	2.814	-
Finn's straight-through path length	2.34	without detritus
Finn's straight-through path length	2.644	with detritus

Cycles and Pathways

A routine based on an approach suggested by Ulanowicz (1986) as implemented in Ecopath was carried out to describe the numerous cycles and pathways that are implied by the food web representing the Arabian Sea ecosystem of Karnataka.

From trophic level I to any consumer: This routine lists all pathways leading from all groups on trophic level I (primary producers and detritus) to any selected consumer. Further, a summary presents the total number of pathways and the mean length of the pathways. The latter is calculated as the total number of trophic links divided by the number of pathways.

The total number of pathways for the Arabian Sea ecosystem of Karnataka was 13110 and the mean length of pathways was estimated as 8.81.

Trophic Level Decomposition

In addition to the routine for calculation of fractional trophic levels, a routine is included in Ecopath, which aggregates the entire system into discrete trophic levels sensu Lindeman. This routine, based on an approach suggested by Ulanowicz (1995), reverses the routine for calculation of fractional trophic levels. Thus, for example where a group obtains 40% of its food as a herbivore and 60% as a first-order carnivore, the relevant fractions of the flow through the group are attributed to the herbivore level and the first consumer level.

The result of these analyses is presented in tables, where the import (on trophic level I only), consumption by predators, export, flows to the detritus, respiration, and throughtput are given by trophic levels. The throughput is the sum of the flows in the other columns. The first table presents flows originating from the primary producers; the second

Table. Trophic level flows from primary producers

Trophic level (TL) \ Flow	Import	Consumption by Predators	Export	Flow to Detritus	Respiration	Throughput
X		0	0	0	0	0
IX		0	0	0	0	0
VIII		0	0	0	0.001	0.002
VII		0.002	0.008	0.012	0.031	0.053
VI		0.053	0.08	0.181	0.512	0.826
V		0.826	0.529	1.873	5.572	8.8
IV		8.8	1.187	23.928	56.828	90.743
III		90.743	0.947	140.851	414.756	647.298
II		647.298	1.325	714.175	2086.604	3449.403
I	0	3449.403	0	645.597	0	4095
Sum	0	4197.125	4.077	1526.619	2564.305	8292.125

Table. Trophic level flows from detritus

Trophic level (TL) \ Flow	Import	Consumption by Predators	Export	Flow to Detritus	Respiration	Throughput
X		0	0	0	0	0
IX		0	0	0	0	0
VIII		0	0	0	0	0
VII		0	0	0	0.001	0.001
VI		0.001	0.004	0.006	0.015	0.026
V		0.026	0.04	0.09	0.255	0.412
IV		0.412	0.27	0.785	2.154	3.62
III		3.62	0.803	31.793	47.816	84.033
II		84.033	1.379	446.224	576.095	1107.731
I	0	1107.73	897.787	0	0	2005.517
Sum	0	1195.823	900.283	478.898	626.336	3201.34

Table. Trophic level flows from detritus and primary producers combined

Trophic level (TL) \ Flow	Import	Consumption by Predators	Export	Flow to Detritus	Respiration	Throughput
X		0	0	0	0	0
IX		0	0	0	0	0
VIII		0	0.001	0.001	0.001	0.002
VII		0.002	0.008	0.012	0.031	0.054
VI		0.054	0.084	0.187	0.527	0.852
V		0.852	0.569	1.964	5.827	9.212
IV		9.212	1.456	24.713	58.982	94.364
III		94.364	1.75	172.645	462.573	731.331
II		731.331	2.704	1160.399	2662.7	4557.134
I	0	4557.133	897.787	645.597	0	6100.517
Sum	0	5392.948	904.36	2005.517	3190.641	11493.46
Extracted to break cycles						28.911
Total throughput						11522.38

summarizes the flows originating from the detritus, while the third table presents the summed flow for the system as a whole.

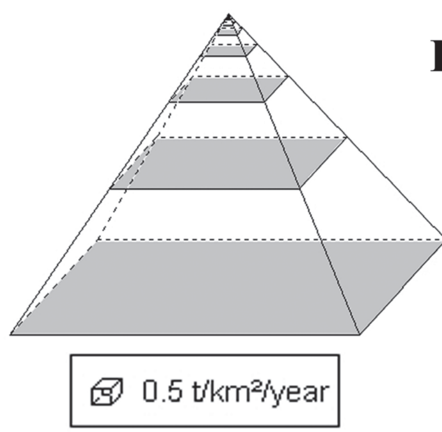
The table with transfer efficiencies can be used for constructing a figure presenting the trophic flows in form of a pyramid. Here, three-dimensional, Egyptian-style, solid pyramids replace the traditional two-dimensional Lindeman pyramids, consisting of a number of rectangles placed on top of each other. These pyramids can be scaled such that the volume of each compartment representing a trophic level is proportional to the total throughput of that level. In addition it is useful, for various comparisons. to make the top angle of the pyramid inversely proportional to the geometric mean of the transfer efficiencies between trophic levels observed in that system.

Trophic pyramids representing the distribution of biomass and energy flow in the Arabian Sea ecosystem off Karnataka

Top angles are inversely proportional to the transfer efficiency (acute angle = high efficiency)
Pyramids are scaled so that volume at each trophic level corresponds to the sum of all flows at that level

Catch Pyramid

Flow Pyramid



Biomass Pyramid

Based on the three tables discussed above, the transfer efficiencies between the successive discrete trophic levels can be calculated as the ratio between the sum of the exports plus the flow that is transferred from one trophic level to the next, and the throughput on the trophic level. This is presented in a table of transfer efficiencies (%) by trophic levels. Efficiency of detritus transfer is not defined since detritus is non-living group. Further, the outputs include the ratio of total flow originating from the detritus to the total flow originating from both primary producers and detritus. This ratio, which may be viewed as an index of the importance of detritus in a system, is the quantitative form of yet another of Odum's (1969) measures of ecosystem maturity. The index is complementary to the proportion of the total flow that originates from the primary producers.

Table. Transfer efficiency-Karnataka Arabian Sea

Source \ Trophic Level	I	II	III	IV	V	VI	VII	VIII	IX	X
Producer		18.8	14.2	11	15.4	16.1	19.2	27.5		
Detritus		7.7	5.3	18.8	16.2	18.9	26.6			
All flows		16.1	13.1	11.3	15.4	16.2	19.3	27.5	30.4	27.3
Proportion of total flow originating from detritus:		0.28								
Transfer efficiencies (calc. as geometric mean for TL II-IV)										
From primary producers: 14.3%										
From detritus: 9.1%										
Total: 13.4%										

Primary Production Required

For terrestrial systems, it has been shown by Vitousek et al. (1986), based on a detailed analysis of agriculture, industry and other activities, that nearly 40% of potential net primary production is used directly or indirectly by these activities. A comparable estimate for aquatic systems were not available until recently, though a rough estimate, of 2% was presented in the same publication. This figure, much lower than that for terrestrial systems, was based on the assumptions that an 'average fish' feeds two trophic levels above the primary producers, and has been since revised upward (Pauly and Christensen, 1995).

The crudeness of the approach for the aquatic systems was due mainly to lack of information on marine food webs, especially on the trophic positions of the various organisms harvested by humans. Models of trophic interactions may however help overcome this situation, and an alternative approach, based on network analysis, may be suggested for quantification of the primary productivity required to sustain harvest by humans (or by analogy by any other group that extracts production from an ecosystem).

To estimate the primary production required (PPR, Christensen and Pauly, 1993) to sustain the catches and the consumption by the trophic groups in an ecosystem the following procedure has been implemented in Ecopath: First, all cycles are removed from the diet compositions, and all paths in the flow network are identified using the method suggested by Ulanowicz (1995). For each path the flows are then raised to primary production equivalents using the product of the catch, the consumption/ production ratio of each path element times the proportion the next element of the path contributes to the diet of the given path element. This is related to the emergy concept of H.T. Odum, and proportional to the ecological footprint.

Table. Estimates of primary production required for harvest of all groups in the Karnataka ecosystem estimated using the network analysis

	Group Name	No. of paths	TL	PPR	Catch	PPR/catch	PPR/Tot PP (%)	PPR/u. catch
1	Marine Mammals	4084	4.06	2.62	0	13814.88	0.06	2.91
2	Sharks	16341	4.45	43.77	0.03	1427.6	0.92	0.3
3	Skates & Rays	7575	3.59	12.73	0.01	1303.22	0.27	0.27
4	Large Pelagics	8802	4.18	160.41	0.19	866.7	3.38	0.18
5	Tunas	2871	4.14	65.45	0.11	575.54	1.38	0.12
6	Cephalopods	981	4.18	362.95	0.28	1304.17	7.66	0.28
7	Large Benthopelagics	4406	4.15	368.6	0.35	1050.26	7.78	0.22
8	Large Benthic Carnivores	1214	4.14	159.63	0.28	565.84	3.37	0.12
9	Medium Benthic Carnivores	251	3.19	51.44	0.33	156.29	1.09	0.03
10	Small Benthic Carnivores	79	2.68	98.68	0.82	120.81	2.08	0.03
11	Small Benthopelagics	1711	3.88	391.44	0.38	1032.42	8.26	0.22
12	Mackerel	3	2	9.46	0.95	10	0.2	0
13	Clupeids	39	2.95	176.74	1.44	122.73	3.73	0.03

14	Anchovies	21	3.49	57.66	0.2	286.97	1.22	0.06
15	Crabs & Lobster	54	2.89	4.65	0.06	76.18	0.1	0.02
16	Shrimps	21	3.02	14.19	0.3	46.57	0.3	0.01
17	Benthic Omnivores	16	2.55	101.46	0.84	120.1	2.14	0.03
18	Heterotrophic Benthos	8	2.32	0	0	-	0	-
19	Meiobenthos	3	2.02	0	0	-	0	-
20	Micro Nekton	5	3.24	0	0	-	0	-
21	Large Zooplankton	2	2.58	0	0	-	0	-
22	Micro Zooplankton	1	2	0	0	-	0	-
23	Phytoplankton	0	1	0	0	-	0	-
	Total	48469	3.04	1825.39	6.57	277.72	44.58	-

Table. Estimates of primary production required for consumption of all groups in the Karnataka ecosystem estimated using network analysis

	Group Name	No. of paths	TL	PPR	Cons.	PPR/cons.	PPR/Tot PP (%)	PPR/u. biom.
1	Marine Mammals	4084	4.06	51.17	0.24	216.7	1.08	0.58
2	Sharks	16341	4.45	61.76	0.11	550.05	1.3	0.99
3	Skates & Rays	7575	3.59	21.24	0.13	164	0.45	0.21
4	Large Pelagics	8802	4.18	227.01	0.64	353.98	4.79	0.78
5	Tunas	2871	4.14	93.15	0.52	177.64	1.96	0.61
6	Cephalopods	981	4.18	1415.1	8.54	165.68	29.85	1.28
7	Large Benthopelagics	4406	4.15	515.44	1.52	339.8	10.87	1.03
8	Large Benthic Carnivores	1214	4.14	1085.58	5.59	194.23	22.9	0.36
9	Medium Benthic Carnivores	251	3.19	82.6	1.78	46.42	1.74	0.16
10	Small Benthic Carnivores	79	2.68	337.31	15.12	22.32	7.12	0.13
11	Small Benthopelagics	1711	3.88	692.51	4.92	140.67	14.61	0.52
12	Mackerel	3	2	15.53	15.51	1	0.33	0.01
13	Clupeids	39	2.95	265.2	11.39	23.28	5.59	0.19
14	Anchovies	21	3.49	1471.63	47.35	31.08	31.04	0.28
15	Crabs & Lobsters	54	2.89	68.42	2.03	33.7	1.44	0.1
16	Shrimps	21	3.02	256.98	15.86	16.2	5.42	0.07
17	Benthic Omnivores	16	2.55	434.39	15.6	27.84	9.16	0.16
18	Heterotrophic Benthos	8	2.32	1754.87	475	3.69	37.02	0.01
19	Meiobenthos	3	2.02	789.59	800	0.99	16.66	0.01
20	Micro Nekton	5	3.24	1466.44	100	14.66	30.93	0.39
21	Large Zooplankton	2	2.58	3057.48	900	3.4	64.5	0.16
22	Micro Zooplankton	1	2	3000	3000	1	63.28	0.06
23	Phytoplankton	0	1	0	0	-	0	0
	Total	48488	-	-	5421.86	-	-	-

Maximum primary production required for harvest of groups was observed for group 11 small benthopelagics, group 7 large benthopelagics and group 6 cephalopods. Maximum primary production required for consumption of groups was observed for lower trophic level groups, viz., micro zooplankton, micro nekton, heterotrophic benthos and anchovies.

The **ecological footprint** concept accounts for all flows of energy and matter to and from an economy and converts these into the corresponding land/water area required from nature to support these flows. The ecological footprints are displayed on the PPR form both as PPR (%), and as PPR per unit biomass or per unit catch. In the Karnataka model, higher trophic level groups had larger ecological footprints indicating that more resources were necessary to sustain their production.

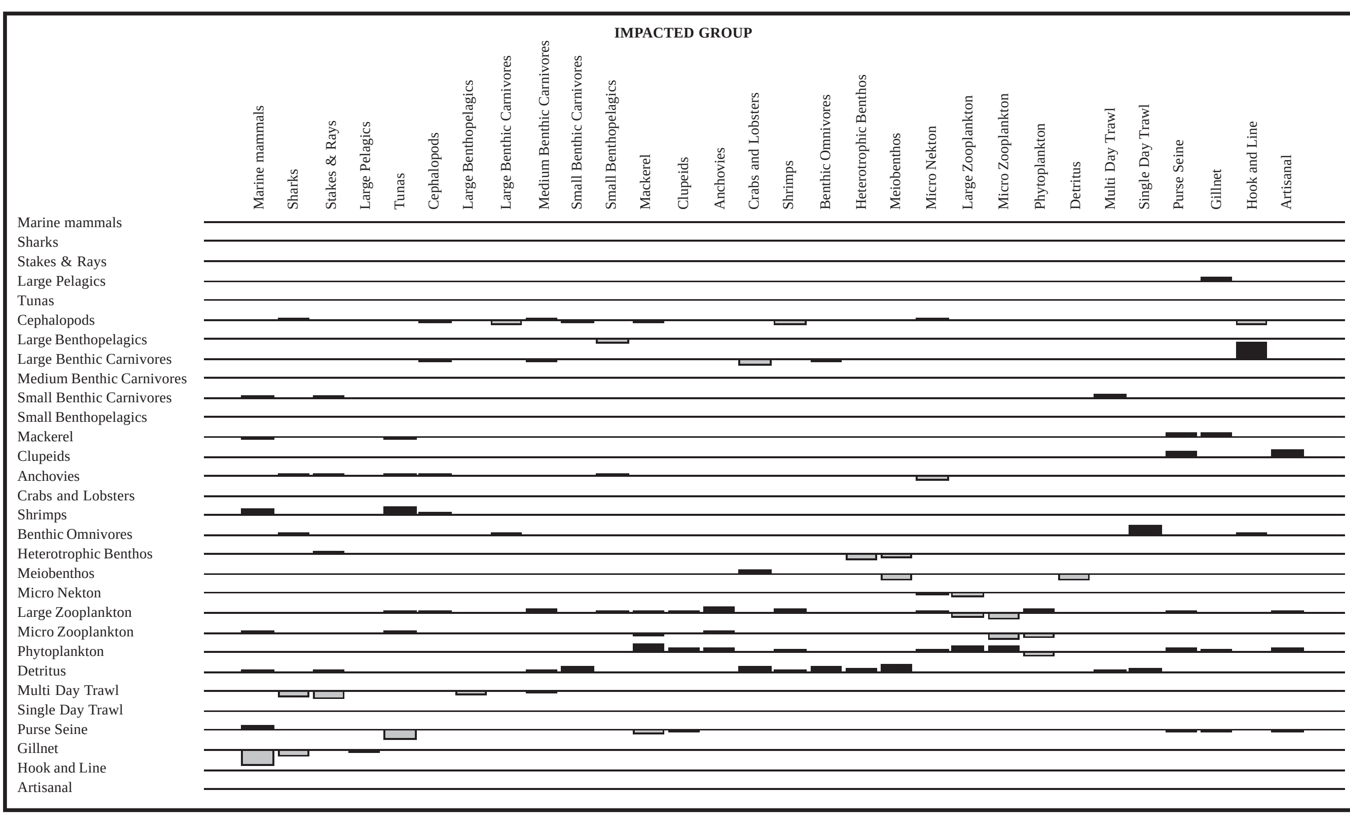
Mixed Trophic Impacts

Leontief (1951) developed a method to assess the direct and indirect interactions in the economy of the USA, using what has since been called the Leontief matrix. This approach was introduced to ecology by Hannon (1973) and Hannon and Joiris (1989). Ulanowicz and Puccia (1990) developed a similar approach, and a routine based on their method has been implemented in the Ecopath system. The mixed trophic impact routine can also be regarded as a form of an ‘ordinary’ sensitivity analysis (Majkowski 1982). One can also therefore regard the impact routine as a tool for indicating the possible impact of direct and indirect interactions (including competition) in a steady-state system.

Some groups have a negative impact on themselves, reflecting increased within-group competition for resources. Exceptions are when a group cannibalises itself (0-order cycle), then the impact may be positive. The gears exploiting also negatively impact many groups. For example purse seines negatively impact tunas, mackerel and clupeids and gillnet negatively impacts marine mammals and sharks. Since anchovies are a food organism for many groups, they have a positive impact on sharks, tunas, cephalopods and small benthopelagics.

Ascendancy

Ascendency is a measure of the average mutual information in a system, scaled by system throughput, and is derived from information theory (Ulanowicz and Norden, 1990). There is an upper limit for the size of the ascendancy and this upper limit is called the development capacity. The difference



The graph shows the direct and indirect impact that the groups mentioned to the left of the histograms (rows) have on the other groups mentioned above the histograms (columns). The bars pointing upwards indicate positive impacts, while the bars pointing downwards show negative impacts. Exploiting gears are also included. The bars should not be interpreted in an absolute sense: the impacts are relative, but comparable between groups.

between the capacity and the ascendency is called 'system overhead'. The overheads provide limits on how much the ascendency can increase and reflect the system's 'strength in reserve' from which it can draw to meet unexpected perturbations (Ulanowicz 1986).

The ascendency, overheads and capacity can be split into contributions from imports, internal flow, exports and dissipation (respiration). These contributions are additive. The unit for these measures is 'flowbits', or the product of flow (t·km^{-2} /year) and bits. Here the 'bits' is an information unit, corresponding to the amount of uncertainly associated with a single binary decision.

The overheads on imports and internal flows (redundancy) may be seen as a measure of system stability sensu Odum, and the ascendency / system throughput ratio as a measure of information, as included in Odum's attributes of ecosystems.

Table. Estimates of group-wise ascendancy

	Group name	Ascendency (t/km²/year*bits)	Overhead (t/km²/year*bits)	Capacity (t/km²/year*bits)	Information (bits)	Throughput (t/km²/year)
1	Marine Mammals	0.292	3.565	3.857	0	0.236
2	Sharks	0.112	1.933	2.045	0	0.112
3	Skates & Rays	0.129	2.152	2.28	0	0.13
4	Large Pelagics	1.284	9.043	10.327	0	0.641
5	Tunas	0.494	7.856	8.35	0	0.524
6	Cephalopods	12.021	89.722	101.742	0.001	8.541
7	Large Benthopelagics	2.363	20.061	22.424	0	1.517
8	Large Benthic Carnivores	14.001	59.516	73.517	0.001	5.589
9	Medium Benthic Carnivores	2.672	23.209	25.881	0	1.779
10	Small Benthic Carnivores	22.862	148.408	171.27	0.002	15.116
11	Small Benthopelagics	6.532	55.64	62.172	0.001	4.923
12	Mackerel	18.0	149.683	167.684	0.002	15.515
13	Clupeids	13.335	119.084	132.42	0.001	11.393
14	Anchovies	72.276	369.306	441.582	0.006	47.353
15	Crabs & Lobster	7.171	22.838	30.009	0.001	2.03
16	Shrimps	43.616	142.505	186.12	0.004	15.859
17	Benthic Omnivores	25.778	154.584	180.362	0.002	15.601
18	Heterotrophic Benthos	507.112	2242.101	2749.214	0.044	475
19	Meiobenthos	745.598	3570.369	4315.967	0.065	800
20	Micro Nekton	130.916	712.578	843.495	0.011	100
21	Large Zooplankton	1034.747	3720.138	4754.885	0.09	900
22	Micro Zooplankton	2693.094	7648.688	10341.78	0.234	3000
23	Phytoplankton	4370.795	6654.216	11025.01	0.379	4095
24	Detritus	4757.356	3491.245	8248.601	0.413	2005.517
	Import					0
	Total	14482.56	29418.44	43901	1.257	11522.377
	(%)	32.989	67.011	100		

Table. Estimates of total ascendancy

Source	Ascendency (flowbits)	Ascendency (%)	Overhead (flowbits)	Overhead (%)	Capacity (flowbits)	Capacity (%)
Import	0	0	0	0	0	0
Internal flow	8741.2	19.9	19705.6	44.9	28446.8	64.8
Export	2254.3	5.1	1144.6	2.6	3398.9	7.7
Respiration	3487	7.9	8568.2	19.5	12055.2	27.5
Totals	14482.6	33	29418.4	67	43901	100

The Arabian Sea ecosystem of Karnataka has a relatively low ascendancy when compared to some other shelf systems. The system overhead is approximately 67%. This suggests that the Arabian Sea ecosystem of Karnataka has significant strength in reserve and can either be resistant or resilient to perturbations with the capability to bounce back quickly to original levels.

Flow Diagram

Often, trophic models are drawn such that the boxes representing organisms low in the food web are placed in the lower part of the graph, along with the plants, while the boxes representing organisms high in the food web are put higher up. In the flow chart incorporated in Ecopath, explicit use is made of this mode of graphing, i.e., to plot the boxes representing the organisms of an ecosystem such that the horizontal axis of symmetry of each box is aligned with the (functional) trophic level of the box in question.

The boxes are assumed to be three dimensional, with their depth (not shown) equal to their height, and the implied volume of each box proportional to the biomass it represents. Flows entering a box do this on the lower half of the box, while flows exiting a box do it from the upper half. Flows that enter a box can be combined, while flows that leave a box cannot branch, but can be merged with flows exiting other boxes. This ensures compatibility with shortcut circuit checks in software for electronic hardware design, and more importantly, it simplifies the flow chart. 'Cannibalism' or zero-order flows are shown as arrows originating from the top half of a box, and moving in a (partial) circle before entering the lower half.

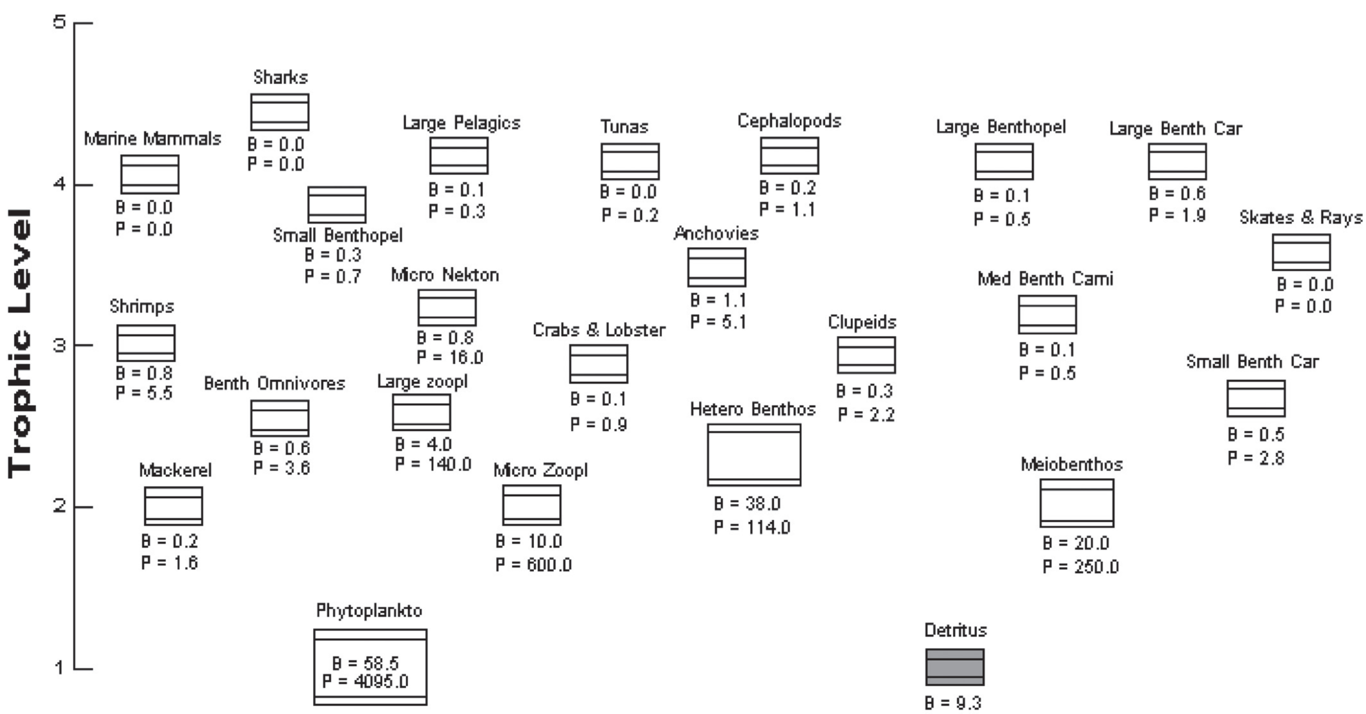


Fig. Diagramatic representation trophic position of different groups and their biomass (B) and production (P)

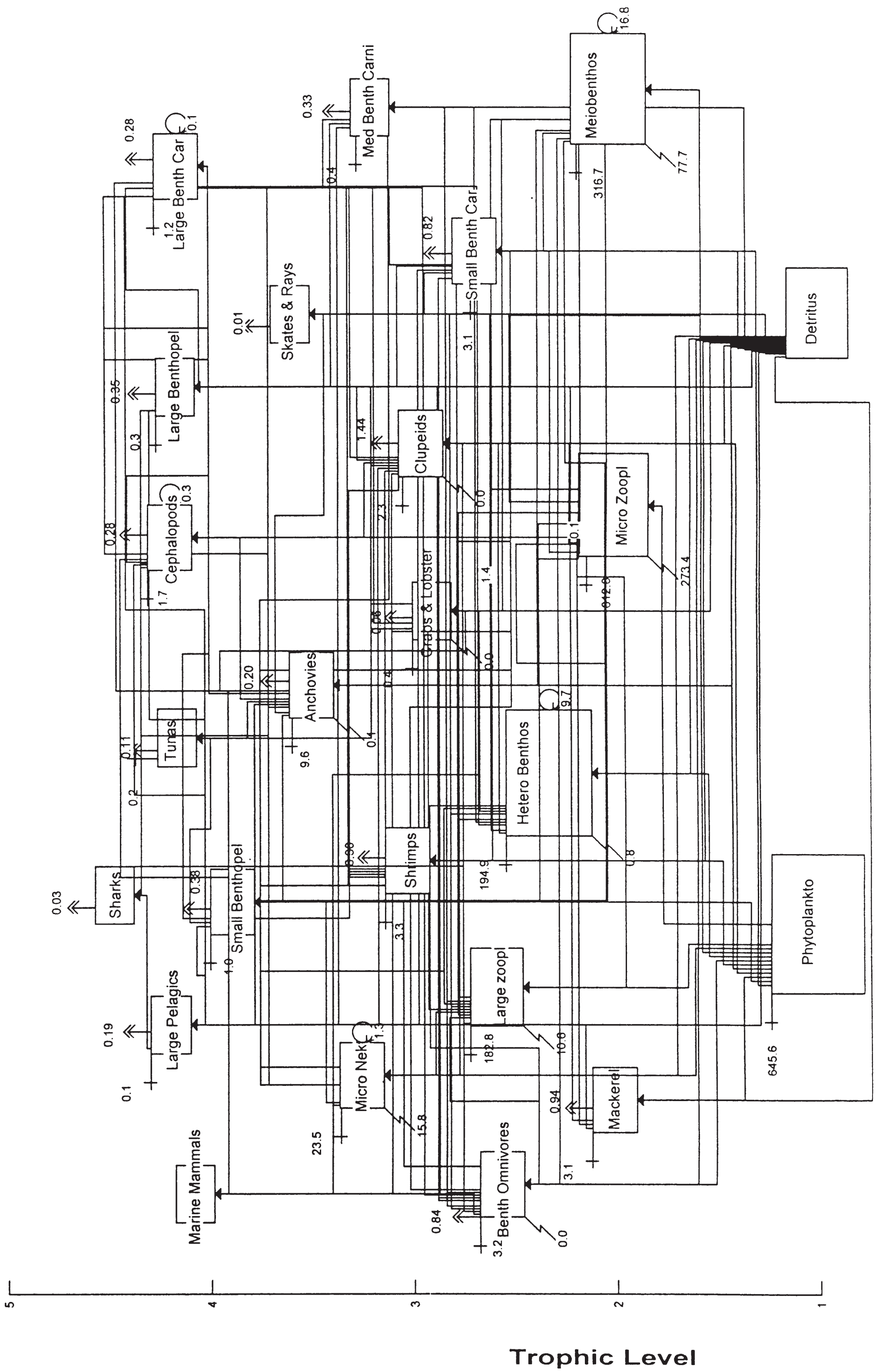


Fig. Flowchart of trophic interactions in the Arabian Sea ecosystem of Karnataka indicating trophic flows in t km^{-2}, fishery catches (double→) and cannibalism (loops). Box sizes represent relative abundance

Comparison with other Ecosystems

Ecosystems	Through put	Catch /PP	PP/B	B/T	Net syst. prod.	Omnivory Index	Ascen-dency	Cycling Index	Path length
Yacutan	2362	0.0029	27.4	0.036	370	0.134	44.0	2.8	2.84
N. Gulf of Mexico	1790	0.0002	7.0	0.015	19	0.195	39.1	2.1	3.03
Venezuela (upwell.)	5309	0.0016	27.0	0.023	831	0.135	39.9	2.2	4.05
Brunei, SE Asia	1816	0.0008	28.6	0.018	300	0.201	29.4	16.3	2.80
Peru 70 (upwell.)	18800	0.0017	87.5	0.012	14709	0.169	38.1	8.7	3.63
Monterey	17513	0.0012	1.2	0.012	2208	0.324	66.2	4.4	3.63
Alaska Gyre	5946		38.1	0.015	407	0.103	42.3		2.03
British Columbia Shelf	1237		21.1	0.180	4106	0.140	40.1		2.03
Bering Sea 50’s	6535	0.0002	5.9	0.050	-115	0.183	32.5	13.2	3.47
Bering Sea 80’s	5692	0.0021	4.9	0.050	-356	0.157	30.9	11.1	3.51
Karnataka Arabian Sea	**11522**	**0.0016**	**29.9**	**0.012**	**904**	**0.299**	**33.0**	**6.03**	**2.81**

A comparison of ecosystem parameters from other parts of the world is given in table (modified from Trites et al., 1999) above. The total throughput for the Arabian Sea ecosystem of Karnataka ranks third after Peru and Monterey Bay and is double that of Bering Sea and Venezuela upwelling ecosystem. The gross efficiency of the fishery (catch/PP) value obtained for Karnataka is close to that of the Peruvian ecosystem, which is also an upwelling ecosystem, harvesting fishes low in the food chain. The omnivory index is quite high comparatively for the Karnataka ecosystem indicating the complex feeding interactions in the ecosystem. The estimated ascendancy values for the Arabian Sea ecosystem of Karnataka indicate that it has not reached its full development capacity, unlike the Yacutan and Monterey Bay ecosystems. The recycling capacity of the ecosystem throughput as indicated by the cycling index shows that recycling in Arabian Sea ecosystem of Karnataka is only moderate as compared to ecosystems like Brunei and Bering Sea.

Dynamic Simulation Using ECOSIM

Ecosim (Walters et. al. 1997) routine in Ecopath was used to investigate how an increase in fishing effort might affect yields and biomass of different fleets (Trawl- MDF and SDF; GN; PS; H&L and AS) operating in the Arabian Sea ecosystem of Karnataka. Ecosim is an extension of Ecopath that can run dynamic and equilibrium simulations. Equilibrium simulations dynamically adjust the ecosystem to compensate for changes in fishing mortality rates. The simulations calculate the equilibrium biomass for all species in the ecosystem over a range of fishing mortality that is directed at one or more species. Dynamic simulations can change fishing mortality rates, and can follow how the effect of fishing on one group is propagated over time through all the others. Dynamic simulations can also simulate a regime shift by changing primary productivity and diet compositions. Assumptions about the available flow of food from one group to another can be evoked in both dynamic and equilibrium models to simulate ‘top-down’ or ‘bottom-up’ control.

Simulation Run Information

Only a very basic simulation with default settings was carried out. The duration of the simulated run was 10 years. Integration steps (per year) which is the step size for the integration of biomass in the ‘fast’ groups was set at the default value of 100 steps per year. The integration method chosen was Adams-Basforth, which is faster, and reportedly more stable. Relaxation parameter is the biomasses change for each integration step. Range for relaxation parameter is [0, 1]. Low value causes slow changes in biomass and a high value fast changes. A medium setting of 0.5 was chosen. The step size used for equilibrium analysis was 0.003. The maximum fishing rate in equilibrium analysis was set at 4 and the number of time steps for averaging results was set at 5.

Maximum relative feeding time: If prey becomes scarce, (e.g., because of predator abundance increases), the predators will have to spend more time feeding (and hence be at a greater risk to predation themselves). This variable helps to limit how much the feeding time may increase. The default value of 2.0 was used. There is empirical evidence showing limits to how great a predation risk organisms are willing to take. Juveniles may for instance be found hiding at food-deprived shorelines even though suitable prey is more abundant in the pelagic zone close by. Going out to there for prey would however place the juveniles at a considerable risk for predation, and they may choose not to do so, or at least to lower the risk by limiting the time spent feeding.

Feeding time factor: This factor determines how fast organisms adjust feeding times so as to stabilize consumption rate per biomass. Setting the value to 0.0 causes feeding time (and hence time exposed to predation risk) to remain constant, all changes in consumption per biomass then result in growth rate changes. Setting it to 1.0 results in fast time response, which causes reduction in vulnerability to predation rather than increased growth rate when/if food density increases. A medium setting of 0.5 was used.

Unexplained predation (Range: [0,1]): This is the proportion of the unexplained natural mortality rate (MO) that is assumed to be sensitive to changes in feeding time. Setting it to 0.0 causes MO to remain constant. Setting it to a higher value causes that proportion of MO to vary in proportion to relative time spent feeding. The value was set at 1.0 (default) allowing for change in MO in proportion with time spent feeding.

Predator effect on feeding time [0,1]: Setting a nonzero value for this parameter allows simulation of direct response of feeding time and food consumption rate to changes in predator abundance, i.e. 'risk sensitive foraging behavior'. Since such information was not available for the ecosystem, the value was set at 0.

The density dependant catchability (Qmax/Q0) and prey consumption rates per predator (QB): foraging time adjustments related to predation risk and/or satiation, and handling time effects were set at default values. The latter ratio are set to large values (1000) by default, which allows predators to increase their feeding rates without limit as prey densities increase (i.e. not limited by time required to handle each prey).

Since the present model did not include any specific juvenile groups for apex predators, no adult-juvenile linkages were provided. One key feature of Ecosim is its ability to allow exploring the implications on system dynamics of different views of how the biomass of different groups in ecosystem is controlled. The two extreme views are 'predator' control' (also called top-down control) and 'prey (or bottom-up) control'.

In the former case, the amount of prey consumed by the predator is the product of predator x prey biomass, i.e., the predators (co-) determine how much of the prey is consumed. Such situation may occur in situation where the prey has no refuge, and is thus always taken upon being encountered by a predator.

Top-down control, also known as Lotka-Volterra dynamics, easily leads to rapid oscillations of prey and predator biomasses and/or unpredictable behavior. The converse (bottom-up control) is the situation that occurs when a prey is protected most of the time (e.g. by hiding in crevices) and becomes available to predators only when it leaves the feature that protects it. Here being caught is a function of the prey's behavior. Bottom-up control usually leads to unrealistically smooth biomass changes in the prey and predator (s) concerned, but which usually do not propagate through the other elements of a food web.

Control values used on Ecosim have been re-scaled such that top down control = 1 and bottom up control = 0, with 0.5 (the default values) indicating 'mixed control'. The default value was used in the present simulation.

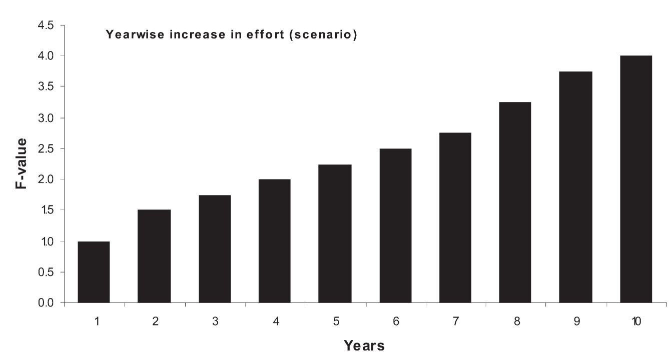
It is not uncommon for some third type of organism (third party mediation) to affect the feeding rate of one type of organism (j) on another (i). At least two types of effects are possible. Facilitation: the third organism type behaves in some way that makes type *i* prey more available to predator *j* when the third organism is more abundant. For example, pelagic piscivores like tuna may drive smaller fishes to the surface, where these fishes are then more available to birds.

Protection: the third organism provides protection for prey type *i* when the third organism is more abundant. For example, juvenile fishes (as type *i* prey) may use corals, macrophytes, and/or sponges for protection from predators, and fishing may directly impact these 'cover' types. An example is, increases in phytoplankton may reduce water clarity and hence search efficiency of visual predators on small fishes, which would tend to reinforce the 'cascade effect' of increasing abundance of small fishes causing reduced zooplankton abundance and hence increased phytoplankton abundance. No third party mediation was assumed in the present simulation.

A routine in Ecosim allows 'forcing function', which may represent physical or other environmental parameters, to influence these trophic interactions. These forcing functions can be used to modify the Q/B ratio of the consumer groups included in an underlying Ecopath file. Since adult-juvenile linkages were not made, and environmental variables were not modeled, no forcing function was applied in the present simulation.

Effort Scenarios

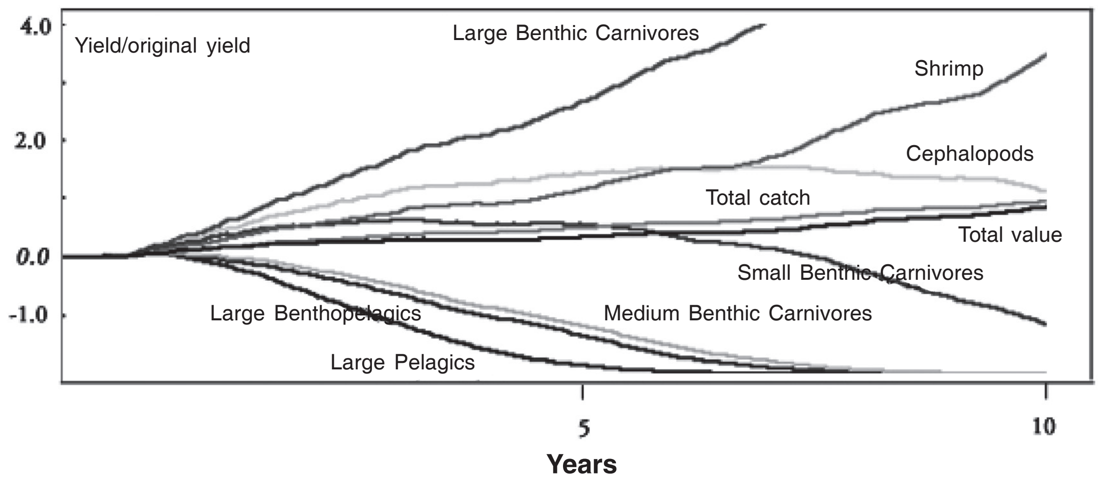
For all the six fleets (MDF, SDF, PS, GN, H&L and AS) exploiting the Arabian Sea ecosystem of Karnataka a graded increase in effort from the present (F value = 1) to 4-times (F = 4) the present effort was simulated as shown below. The average rate of increase modeled was 17% per annum.



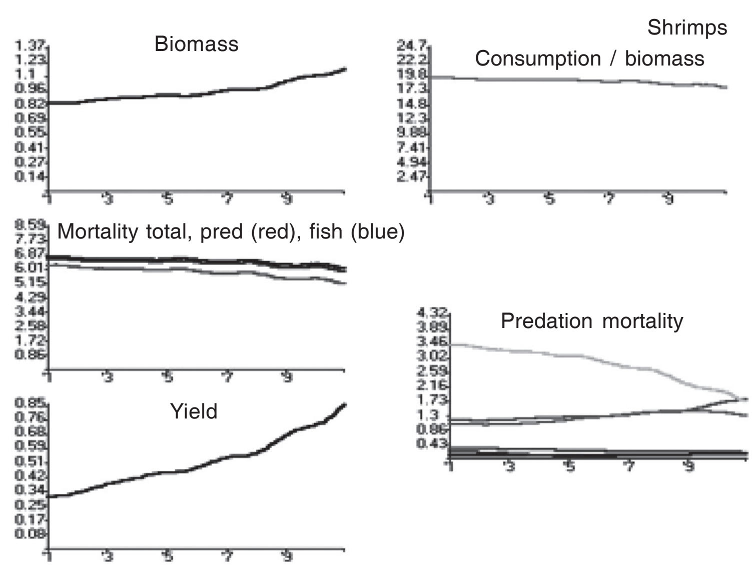
ECOSIM Simulation Results

Multi-day Fleet (MDF) of trawl

ECOSIM simulation of yields of important components in Multi-day fleet of trawlers along Karnataka Coast with varying effort regimes over a 10 year time-scale



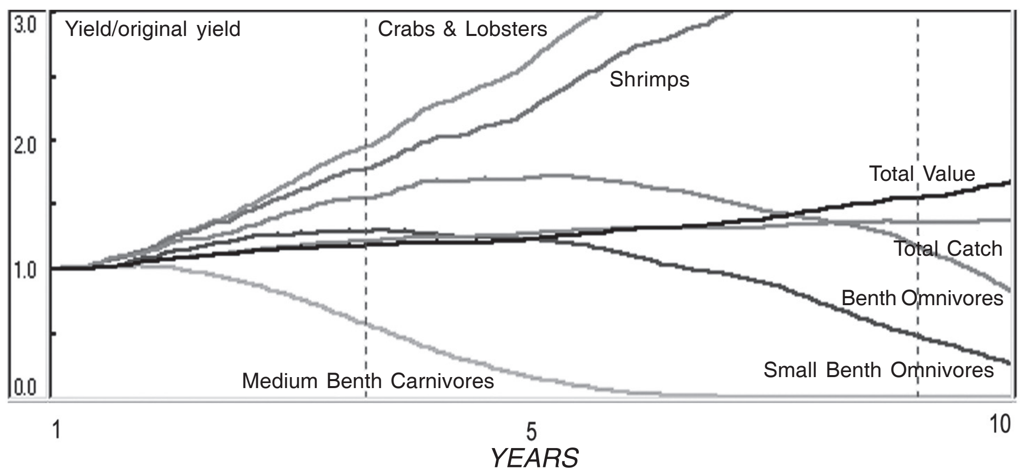
Simulation of Shrimp yields, biomass, mortalities and consumption in MDF under varying effort scenarios



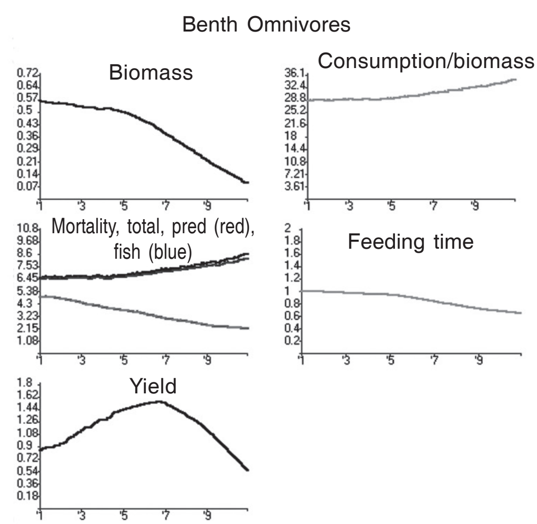
Simulation results indicate that with the simulated effort increase the yield of shrimps and large benthic carnivores (Rock cods, serranids, lutjanids and lizard fishes) are likely to increase manifold. The yield of cephalopods is also likely to increase for the first 5 years and then decline. However, the yields of large benthopelagics (ribbon fish, horse mackerel, wolf herring and catfishes) are likely to suffer a rapid decline in yield within 5 years. Other groups, which are also prone to decline, are large pelagics and small and medium benthic carnivores. The latter two groups contribute to the bulk of the catch in MDF. Overall the total catch in MDF and its value show only a marginal increase, indicating that increase in effort from the present level for MDF is not warranted.

Single-day Fleet (SDF) of trawl

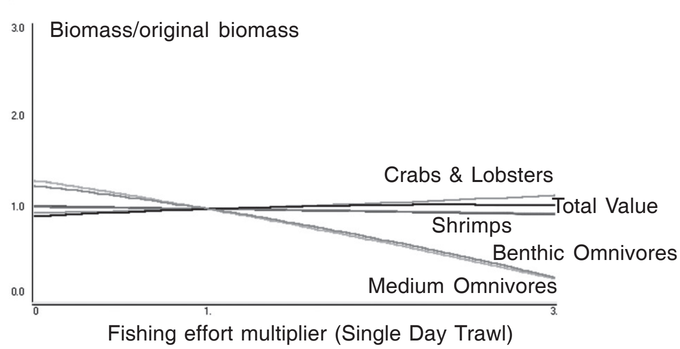
ECOSIM simulation of yields of important resources in SDF trawlers along Karnataka coast with varying effort regimes over a 10-year time scale



Simulation of Benthic Omnivore yields, biomass, mortalities and consumption



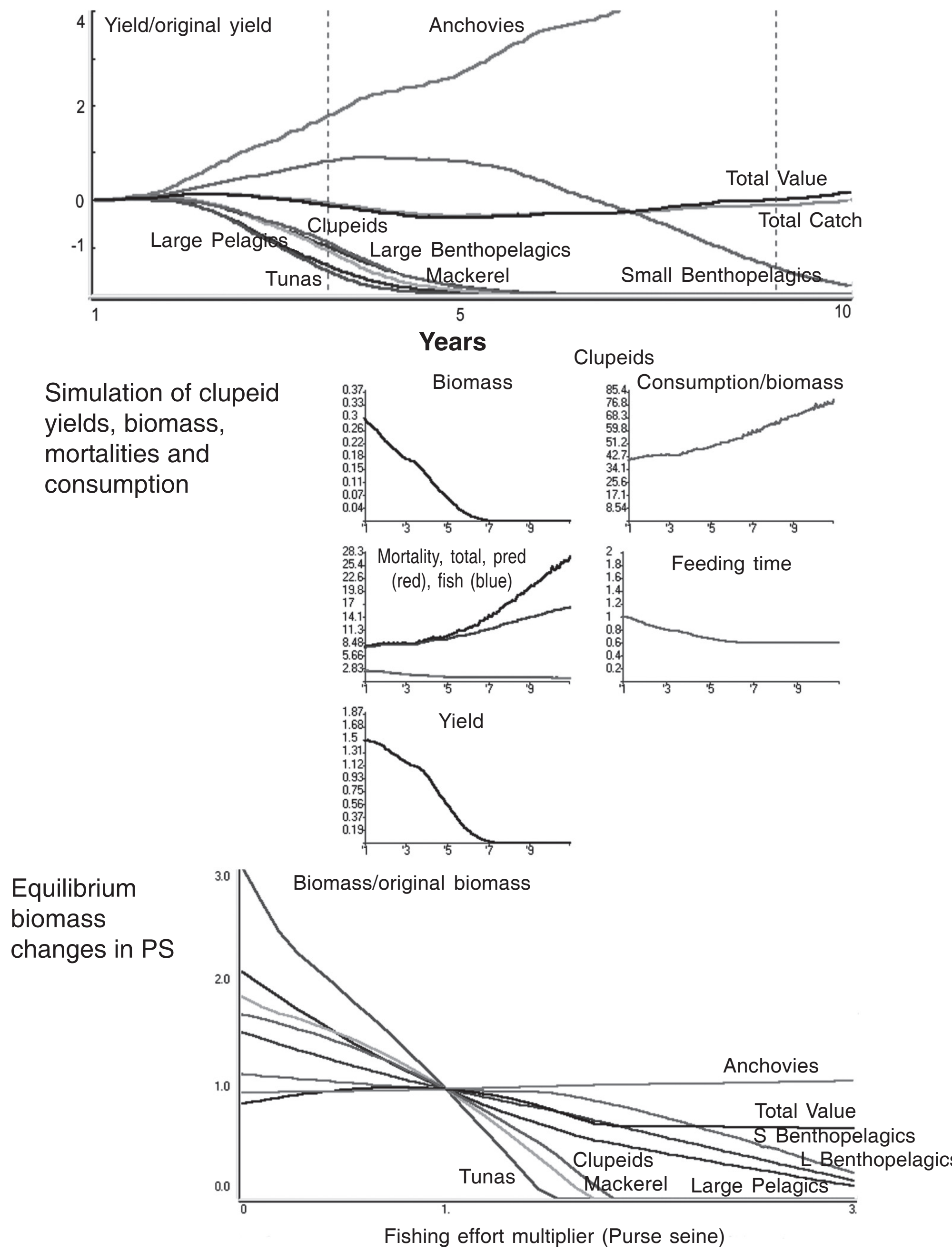
Equilibrium biomass changes in SDF



Simulation results indicate that while the yields of crabs and lobsters and shrimps are likely to increase with increase in effort, the total catch and value of the SDF is unlikely to increase substantially. The yields and biomass of benthic omnivores (mainly flatfishes and Squilla) and medium benthic carnivores (mainly sciaenids) are liable to decline drastically. Therefore, effort increase in SDF is not recommended.

Purse Seine Fleet (PS)

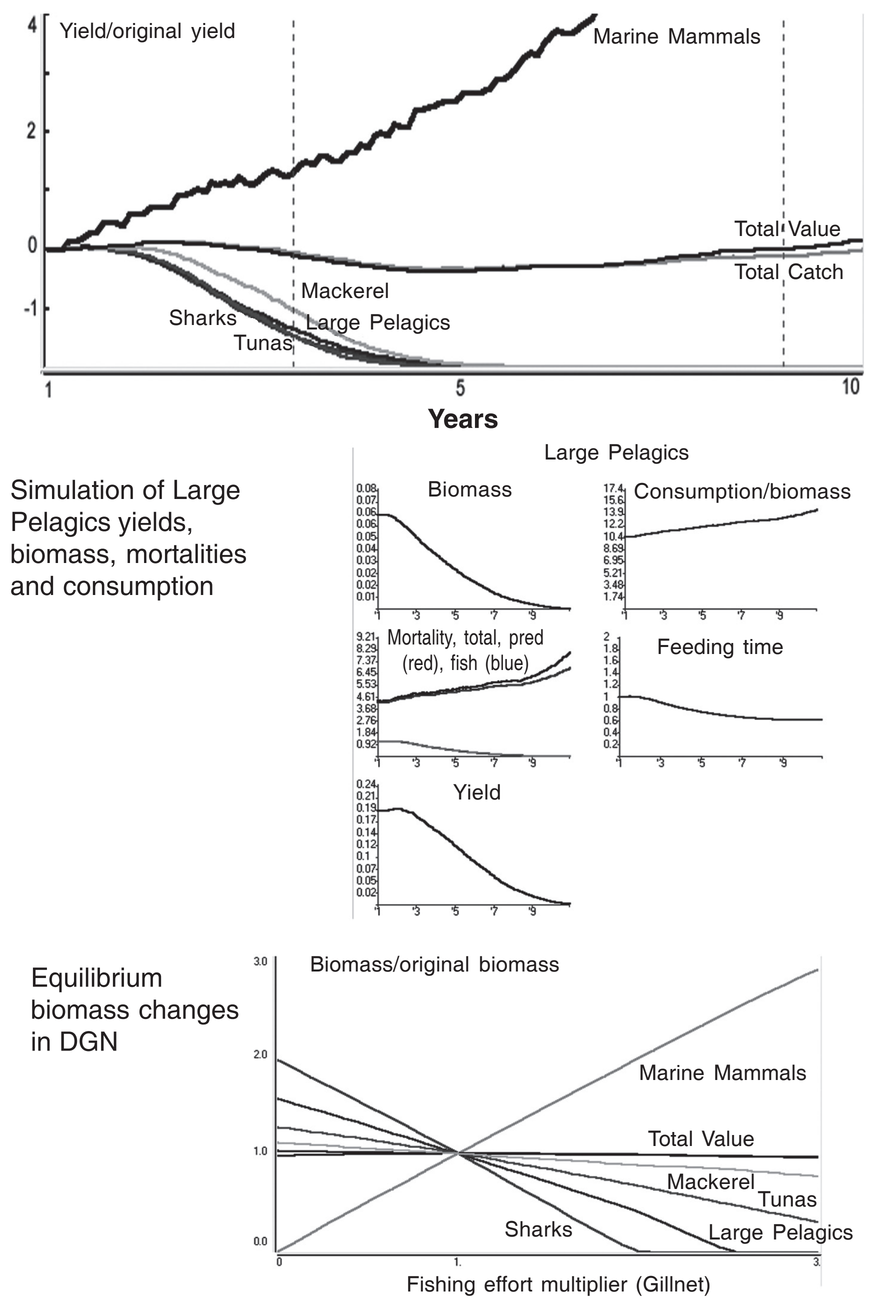
ECOSIM simulation of yields of important resources in Purse seine fleet along Karnataka coast with varying effort regimes over a 10-year time scale



With the keyed in effort increase scenario all the resources exploited by PS except anchovies show a declining trend in yield and biomass. Yields of groups like clupeids (oil sardine and lesser sardines), mackerel, large pelagics and tunas show a very rapid (within 5 years) decline. The total catch and value, which show a dip during the first 5 years, are likely to return to the present level within 10 years. Considering these results, an effort increase in PS fleet is not recommended.

Drift Gillnet Fleet (DGN)

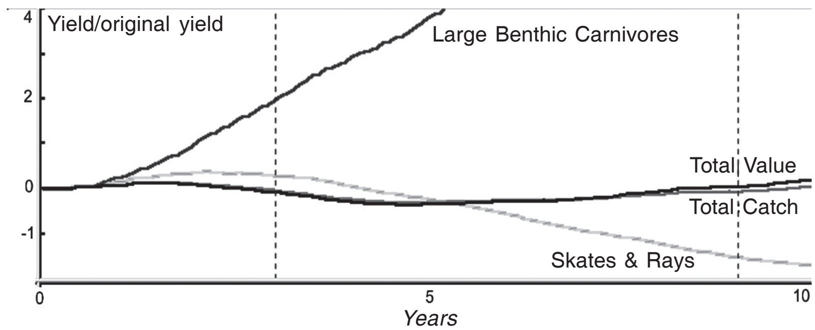
ECOSIM simulation of yields of important resources in DGN fleet along Karnataka coast with varying effort regimes over a 10-year time scale



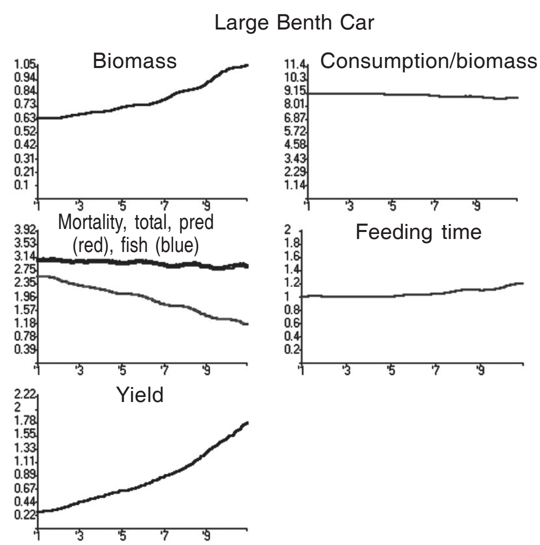
The simulation results for DGN shows that while the marine mammal (which are not targeted, but incidental catches) yields are likely to increase manifold; all commercially important groups are likely to suffer a decline in yield and biomass with increase in effort. The total catch and value of the fishery are also prone to decrease and therefore, an effort increase in DGN fleet is not recommended.

Hook and Line Fleet (H & L)

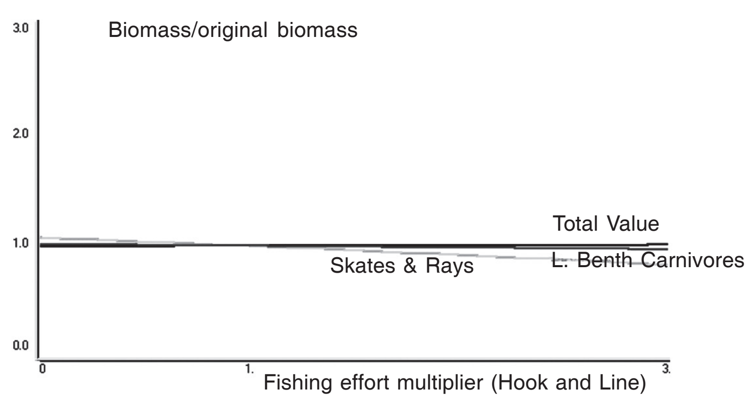
ECOSIM simulation of yields of important resources in Hook & Line fleet along Karnataka coast with varying effort regimes over a 10-year period



Simulation of Large Benthic Carnivores yields, biomass, mortalities and consumption



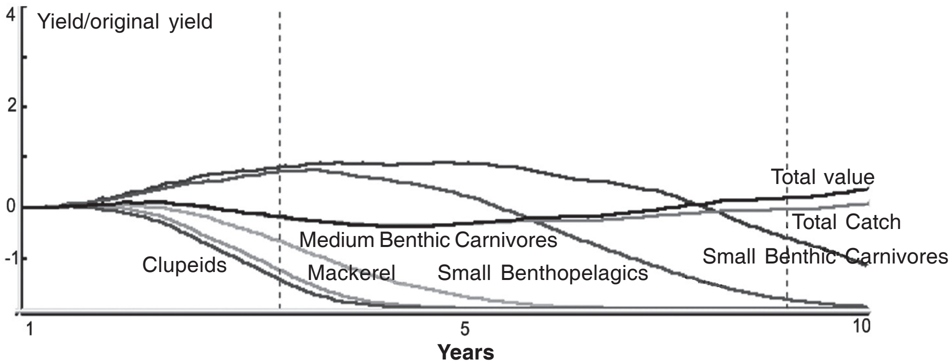
Equilibrium biomass changes in H&L



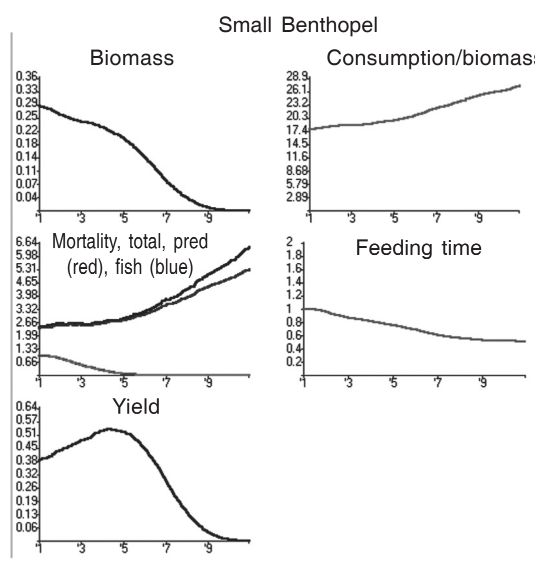
The simulation results for H&L fleet shows that the yields of large benthic carnivores (mainly *Pristipomoides filamentosus* and rock cods) can be markedly improved by increasing the effort. However beyond an F-value of 2 it would drastically affect skates and rays biomass. And since, the total value does not show much increase, a recommendation for increase in effort can be made only when there is a substantial increase in the price structure of *P. filamentosus* and rock cods.

Artisanal Fleet (AS)

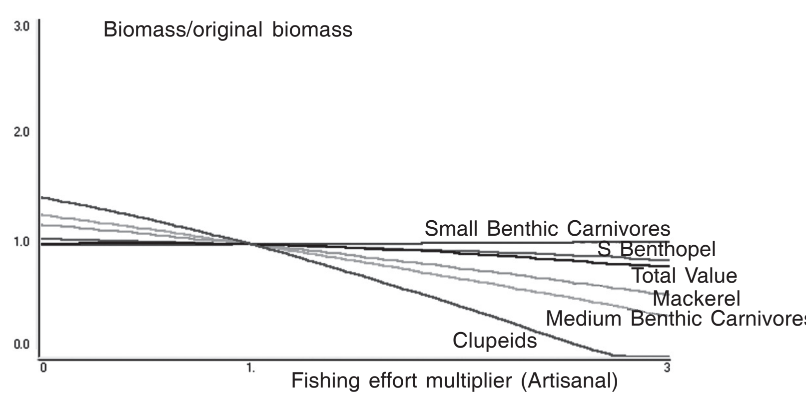
ECOSIM simulation of yields of important resources in AS fleet along Karnataka coast with varying effort regimes over a 10-year time scale



Simulation of Small Bentopelagics yields, biomass, mortalities and consumption



Equilibrium biomass changes in AS



An increase in fishing effort of the AS fleet results only in marginal increase in yields of small benthopelagics and small benthic carnivores during the first 5 years and subsequently an overall decline by 10 years. The yields and biomass of clupeids and mackerel show a drastic decline within 5 years. The total catch and value does not show much change, and therefore, an increase in effort for the AS fleet cannot be recommended.

Summary and Conclusions

1. A trophic mass-balance model of the marine ecosystem of the Arabian Sea off Karnataka incorporating energy flows between trophic levels and interaction between trophic components was constructed using the Ecopath with Ecosim (EwE, Ver. 5.0) software.

2. The Karnataka model encompassed an area of 27,000 km^2 and had 24 functional ecological groups of which 23 were living groups and one dead group (detritus). Ecological groupings were made taking into consideration that within group, the species have similar sizes, similar population parameters, similar food and similar predators, and they ranged from apex predators like marine mammals, sharks and tunas to micro zooplankton and detritus. The study period was from 1999 to 2001 and an average picture during this period is presented.

3. The input parameters used for the model fitting were the ecological group-wise estimates of production biomass (P/B) ratio, consumption biomass (Q/B) ratio, biomass, diet composition and fleet-wise and group-wise fishery catches. The quality of the inputted data was assessed with the Ecopath pedigree index and the value obtained was 0.521 (scale 0-1).

4. The total system throughput represents the size of the entire system in terms of flow and was estimated for Arabian Sea ecosystem of Karnataka as 11,522 t/km^2/year, which is comparatively high, but is consistent with tropical marine ecosystems with high turnover. The Karnataka model had a mean trophic level of 3.04, with the minimum being 1 (phytoplankton) and maximum 4.45 (sharks).

5. Gross efficiency of the fishery is computed as the ratio between the total catch and the total primary production in the system. For the Karnataka model the value obtained was 0.0016 (higher than the global average) indicating a fishery harvesting fishes low in the food chain. The Arabian Sea ecosystem of Karnataka is well known as being part of the Malabar upwelling system where lower trophic level pelagic fishes dominate. The system omnivory index is a measure of how the feeding interactions are distributed between trophic levels. For the Arabian Sea ecosystem of Karnataka an index value of 0.299 was obtained.

6. The total primary production by total respiration ratio is considered by Odum to be an important ratio for description of the maturity of an ecosystem. According to Odum's classification the Arabian Sea ecosystem of Karnataka is in a developing stage with ratio being greater than 1 (1.283). The estimates of net system production and total primary production by total biomass ratio also indicated that the ecosystem is immature.

7. The predation mortality rates (M2) were considerably higher than fishing mortality rate among the commercially exploited groups with respect to cephalopods (Grp 6), large benthic carnivores (Grp 8), small benthic carnivores (Grp 10), anchovies (Grp 14), crabs and lobsters (Grp 15), shrimps (Grp 16) and benthic omnivores (Grp 17). This indicates the predation pressure exerted on these groups by other groups. The top 3 apex predator groups and tunas had no predatory pressure.

8. The flows to detritus were maximum for phytoplankton and micro zooplankton followed by meiobenthos and heterotrophic benthos. The least flows were observed for apex predators. The omnivory index (OI) was calculated as the variance of the trophic level of a consumer's prey groups. The maximum OI was observed for Group 9 medium benthic carnivores, followed by Group 10 clupeids and Group 4 large pelagics indicating feeding on a wide variety of preys. Highly specialized feeding (low OI) was observed for tunas and mackerel. Higher consumption was estimated for groups in the lower trophic levels. Maximum was observed for micro-zooplankton (3000 t/km^2/year).

9. The prey and predator niche overlaps for the Arabian Sea ecosystem of Karnataka indicates that tunas, cephalopods and large benthic carnivores have significant overlap in their diets with marine mammals. Maximum prey overlaps were observed for group 9, medium benthic carnivores. Similarly, large pelagics and large benthopelagics had significant predator overlaps. Maximum predatory overlap was observed in the case of cephalopods.

10. The selection indices or electivity describe a predator's preference for prey and in the Arabian Sea ecosystem of Karnataka sharks had a marked preference for large pelagics, while it avoided small benthic carnivores and small benthopelagics. Group 9 medium benthic were very selective feeders (on benthic omnivores and large zooplankton) avoiding most prey groups. The search rates (volume searched per unit time by a given predator j seeking a certain prey i) for groups of the Arabian Sea ecosystem of Karnataka indicated that higher trophic level groups had higher search rates than lower trophic level groups.

11. The numerous cycles and pathways that are implied by the food web representing the Arabian Sea ecosystem of Karnataka were described. The total number of pathways was 13110 and the mean length of pathways was estimated as 8.81. Trophic pyramids representing the distribution of biomass and energy flow was constructed. The transfer efficiency from primary producers was estimated as 14.3% and from detritus 9.1%.

12. Maximum primary production required for harvest of groups was observed for group 11 small benthopelagics, group 7 large benthopelagics and group 6 cephalopods. Maximum primary production required for consumption of groups was observed for lower trophic level groups, viz., micro zooplankton, micro nekton, heterotrophic benthos and anchovies. In the Karnataka model, higher trophic level groups had larger ecological footprints (PPR per unit biomass) indicating that more resources were necessary to sustain their production.

13. The mixed trophic impact analysis indicated that purse seines negatively impact tunas, mackerel and clupeids and gillnet negatively impacts marine mammals and sharks. Since anchovies are a food organism for many groups, they have a positive impact on sharks, tunas, cephalopods and small benthopelagics.

14. The Arabian Sea ecosystem of Karnataka has a relatively low ascendancy (33%) when compared to some other shelf systems. The system overhead is approximately 67%. This suggests that the Arabian Sea ecosystem of Karnataka has significant strength in reserve and can either be resistant or resilient to perturbations with the capability to bounce back quickly to original levels. A trophic flow diagram was constructed such that boxes representing organisms low in the food web are placed in the lower part of the graph, along with the plants, while the boxes representing organisms high in the food web are put higher up. The boxes were connected by means of trophic flows.

15. Simulation exercises using Ecosim with a 17% per annum effort increase over a period of 10 years in all fleets indicated the following.

    a. The total catch in MDF and its value show only a marginal increase, indicating that increase in effort from the present level for MDF is not warranted.

    b. The yields and biomass of benthic omnivores (mainly flatfishes and Squilla) and medium benthic carnivores (mainly sciaenids) are liable to decline drastically in SDF and, therefore, effort increase in SDF is not recommended.

    c. The total catch and value in PS, which show a dip during the first 5 years, are likely to return to the present level within 10 years. Considering these results, an effort increase in PS fleet is not recommended.

    d. The total catch and value of the fishery in DGN are prone to decrease and therefore, an effort increase in DGN fleet is not recommended.

    e. The simulation results for H&L fleet shows that the yields of large benthic carnivores (mainly *Pristipomoides filamentosus* and rock cods) can be markedly improved by increasing the effort. However, the total value does not show much increase, therefore, a recommendation for increase in effort can be made only when there is a substantial increase in the price structure of *P. filamentosus* and rock cods.

    f. The total catch and value in AS fleet does not show much change, and therefore, an increase in effort for the AS fleet cannot be recommended.

16. The present ecological model constructed and the simulations made are a preliminary exercise and with the availability of better information and more vigorous data the model can be improved so as to reflect the reality in a better fashion. This study shows that ecological modeling is a much better tool for management of multispecies marine fishery resources and should be applied to other major marine ecosystems in India.

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Output Data Appendices

Table. Original diet matrix used as input for ECOPATH run

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Marine Mammals																						
2	Sharks																						
3	Skates & Rays																						
4	Large Pelagics		0.032		0.013																		
5	Tunas																						
6	Cephalopods	0.041	0.152		0.065	0.000	0.045	0.037	0.200	0.039		0.005											
7	Large Benthopelagics		0.047	0.000	0.038			0.010															
8	Large Benthic Carnivores	0.228		0.004	0.030		0.190	0.038	0.028	0.004		0.063											
9	Medium Benthic Carnivores		0.210		0.046			0.005	0.123	0.002													
10	Small Benthic Carnivores	0.167	0.005	0.298	0.100	0.001	0.120	0.033	0.068	0.205	0.008	0.048											
11	Small Benthopelagics	0.316	0.313	0.007	0.221	0.022		0.115	0.001		0.013												
12	Mackerel				0.030		0.020	0.002	0.000														
13	Clupeids	0.025	0.108	0.001	0.045	0.206	0.233	0.040	0.005	0.042		0.003											
14	Anchovies	0.012	0.059	0.043	0.333	0.392	0.160	0.570	0.348	0.075	0.146	0.354	0.000	0.156		0.352							
15	Crabs & Lobsters			0.008	0.021		0.024	0.051	0.069	0.048	0.044	0.000											
16	Shrimps	0.176	0.011	0.590	0.005	0.375	0.195	0.037	0.085	0.212	0.222	0.438		0.069	0.028	0.511		0.028					
17	Benthic Omnivores	0.035	0.060	0.014	0.045	0.003	0.013	0.032	0.057	0.119	0.131	0.014		0.006	0.099		0.013	0.018					
18	Heterotrophic Benthos		0.000	0.022				0.000	0.000	0.003	0.004	0.000		0.001	0.009	0.020	0.008	0.174	0.020				
19	Meiobenthos		0.001			0.001				0.001	0.021	0.006			0.008	0.085	0.100	0.189	0.140	0.021			
20	Micro Nekton			0.000	0.002			0.022	0.017	0.060	0.041	0.028		0.074	0.083		0.010				0.010		
21	Large Zooplankton	0.000	0.000					0.000		0.107	0.078	0.025	0.000	0.330	0.588		0.658	0.108	0.080		0.612		
22	Micro Zooplankton									0.002	0.068	0.002	0.002	0.129	0.162		0.012	0.002	0.050	0.003	0.283	0.687	
23	Phytoplankton									0.001	0.011	0.004	0.890	0.176	0.004		0.004	0.019	0.100	0.001	0.060	0.313	1.000
24	Detritus		0.001	0.014	0.003			0.007		0.080	0.214	0.010	0.107	0.058	0.020	0.032	0.195	0.461	0.610	0.975	0.035	0.000	
	Import																						
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table. Modified diet matrix after balancing the model with auto-mass balance routine of ECOPATH

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Marine Mammals																						
2	Sharks																						
3	Skates & Rays																						
4	Large Pelagics		0.192		0.078																		
5	Tunas																						
6	Cephalopods	0.071	0.107		0.079	0.000	0.031	0.062	0.057	0.000		0.005											
7	Large Benthopelagics		0.134	0.002	0.105			0.031															
8	Large Benthic Carnivores	0.073		0.013	0.042		0.129	0.061	0.023	0.000		0.046											
9	Medium Benthic Carnivores		0.025		0.056			0.009	0.025	0.000													
10	Small Benthic Carnivores	0.201	0.010	0.352	0.126	0.002	0.122	0.064	0.065	0.000	0.000	0.048											
11	Small Benthopelagics	0.000	0.003	0.022	0.027	0.056		0.146	0.001		0.000												
12	Mackerel				0.092		0.059	0.007	0.000														
13	Clupeids	0.045	0.110	0.003	0.057	0.211	0.044	0.062	0.004	0.000		0.003											
14	Anchovies	0.036	0.143	0.171	0.087	0.229	0.231	0.005	0.266	0.000	0.000	0.211	0.000	0.000		0.037							
15	Crabs & Lobsters			0.027	0.035		0.021	0.091	0.084	0.000	0.000	0.000											
16	Shrimps	0.428	0.034	0.006	0.015	0.480	0.325	0.112	0.169	0.000	0.000	0.171		0.000	0.000	0.003		0.000					
17	Benthic Omnivores	0.142	0.224	0.075	0.164	0.016	0.038	0.128	0.189	0.057	0.041	0.045		0.000	0.000		0.000	0.000					
18	Heterotrophic Benthos		0.003	0.198				0.000	0.002	0.013	0.010	0.002		0.002	0.013	0.140	0.012	0.197	0.020				
19	Meiobenthos		0.008			0.007				0.004	0.051	0.040			0.012	0.596	0.154	0.214	0.143	0.021			
20	Micro Nekton			0.004	0.015			0.168	0.114	0.258	0.099	0.189		0.125	0.121		0.015				0.013		
21	Large Zooplankton	0.003	0.000					0.001		0.312	0.127	0.134	0.000	0.322	0.631		0.504	0.045	0.069		0.588		
22	Micro Zooplankton									0.007	0.131	0.012	0.000	0.157	0.188		0.010	0.001	0.041	0.002	0.281	0.584	
23	Phytoplankton									0.004	0.026	0.027	0.893	0.297	0.006		0.006	0.022	0.102	0.001	0.075	0.416	1.000
24	Detritus		0.008	0.126	0.022			0.053		0.344	0.515	0.067	0.107	0.098	0.029	0.224	0.299	0.522	0.624	0.976	0.043		
	Import																						
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table. Estimated predation mortality rates of different groups

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Marine Mammals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Sharks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Skates & Rays	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Large Pelagics	-	0.351	-	0.815	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Tunas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Cephalopods	0.072	0.052	-	0.217	0.000	1.123	0.404	1.368	0.000	-	0.096	-	-	-	-	-	-	-	-	-	-	-
7	Large Benthopelagics	-	0.142	0.002	0.635	-	-	0.447	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Large Benthic Carnivores	0.028	-	0.003	0.043	-	1.756	0.148	0.204	0.000	-	0.362	-	-	-	-	-	-	-	-	-	-	-
9	Medium Benthic Carnivores	-	0.026	-	0.332	-	-	0.120	1.267	0.000	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Small Benthic Carnivores	0.090	0.002	0.086	0.152	0.002	1.963	0.183	0.687	0.000	0.000	0.450	-	-	-	-	-	-	-	-	-	-	-
11	Small Benthopelagics	0.000	0.001	0.010	0.060	0.103	-	0.789	0.019	-	0.000	-	-	-	-	-	-	-	-	-	-	-	-
12	Mackerel	-	-	-	0.238	-	2.033	0.041	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Clupeids	0.037	0.043	0.001	0.126	0.382	1.290	0.324	0.083	0.000	-	0.046	-	-	-	-	-	-	-	-	-	-	-
14	Anchovies	0.008	0.014	0.020	0.050	0.108	1.779	0.007	1.342	0.000	0.000	0.938	0.000	0.000	-	0.068	-	-	-	-	-	-	-
15	Crabs & Lobsters	-	-	0.025	0.162	-	1.277	0.984	3.368	0.000	0.000	0.009	-	-	-	-	-	-	-	-	-	-	-
16	Shrimps	0.122	0.005	0.001	0.011	0.304	3.359	0.205	1.140	0.001	0.000	1.017	-	0.000	0.000	0.007	-	0.000	-	-	-	-	-
17	Benthic Omnivores	0.060	0.045	0.018	0.190	0.015	0.589	0.348	1.898	0.183	1.113	0.396	-	0.000	0.000	-	0.000	0.000	-	-	-	-	-
18	Heterotrophic Benthos	-	0.000	0.001	-	-	-	0.000	0.000	0.001	0.004	0.000	-	0.001	0.016	0.007	0.005	0.081	0.256	-	-	-	-
19	Meiobenthos	-	0.000	-	-	0.000	-	-	-	0.000	0.038	0.010	-	-	0.028	0.060	0.122	0.167	3.399	0.841	-	-	-
20	Micro Nekton	-	-	0.001	0.012	-	-	0.319	0.799	0.573	1.866	1.163	-	1.776	7.184	-	0.307	-	-	-	1.565	-	-
21	Large Zooplankton	0.000	0.000	-	-	-	-	0.000	-	0.139	0.479	0.165	0.000	0.917	7.465	-	1.997	0.176	8.249	-	14.711	-	-
22	Micro Zooplankton	-	-	-	-	-	-	-	-	0.001	0.199	0.006	0.000	0.179	0.890	-	0.015	0.001	1.950	0.156	2.807	52.595	-
23	Phytoplankton	-	-	-	-	-	-	-	-	0.000	0.007	0.002	0.237	0.058	0.005	-	0.002	0.006	0.830	0.014	0.128	6.394	51.282

Table. Estimates of consumption for all groups expressed using t / km² / year as unit

Grp	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24
1	Marine Mammals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
2	Sharks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
3	Skates & Rays	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
4	Large Pelagics	-	0.02	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13
5	Tunas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15
6	Cephalopods	0.02	0.01	-	0.05	0.00	0.26	0.10	0.32	0.00	-	0.02	-	-	-	-	-	-	-	-	-	-	-	1.74
7	Large Benthopelagics	-	0.02	0.00	0.07	-	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.31
8	Large Benthic Carnivores	0.02	-	0.00	0.03	-	1.10	0.09	0.13	0.00	-	0.23	-	-	-	-	-	-	-	-	-	-	-	1.16
9	Medium Benthic Carnivores	-	0.00	-	0.04	-	-	0.01	0.14	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	0.37
10	Small Benthic Carnivores	0.05	0.00	0.05	0.08	0.00	1.04	0.10	0.36	0.00	0.00	0.24	-	-	-	-	-	-	-	-	-	-	-	3.08
11	Small Benthopelagics	0.00	0.00	0.00	0.02	0.03	-	0.22	0.01	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	1.00
12	Mackerel	-	-	-	0.06	-	0.51	0.01	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.13
13	Clupeids	0.01	0.01	0.00	0.04	0.11	0.37	0.09	0.02	0.00	-	0.01	-	-	-	-	-	-	-	-	-	-	-	2.32
14	Anchovies	0.01	0.02	0.02	0.06	0.12	1.98	0.01	1.49	0.00	0.00	1.04	0.00	0.00	-	0.08	-	-	-	-	-	-	-	9.59
15	Crabs & Lobsters	-	-	0.00	0.02	-	0.18	0.14	0.47	0.00	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	0.43
16	Shrimps	0.10	0.00	0.00	0.01	0.25	2.78	0.17	0.94	0.00	0.00	0.84	-	0.00	0.00	0.01	-	0.00	-	-	-	-	-	3.29
17	Benthic Omnivores	0.03	0.03	0.01	0.11	0.01	0.33	0.19	1.06	0.10	0.62	0.22	-	0.00	0.00	-	0.00	0.00	-	-	-	-	-	3.19
18	Heterotrophic Benthos	-	0.00	0.03	-	-	-	0.00	0.01	0.02	0.15	0.01	-	0.02	0.62	0.29	0.19	3.07	9.71	-	-	-	-	194.88
19	Meiobenthos	-	0.00	-	-	0.00	-	-	-	0.01	0.76	0.20	-	-	0.55	1.21	2.44	3.34	67.99	16.82	-	-	-	316.68
20	Micro Nekton	-	-	0.00	0.01	-	-	0.26	0.64	0.46	1.49	0.93	-	1.42	5.75	-	0.25	-	-	-	1.25	-	-	23.55
21	Large Zooplankton	0.00	0.00	-	-	-	-	0.00	-	0.56	1.92	0.66	0.00	3.67	29.86	-	7.99	0.70	33.00	-	58.85	-	-	182.80
22	Micro Zooplankton	-	-	-	-	-	-	-	-	0.01	1.99	0.06	0.00	1.79	8.90	-	0.15	0.01	19.50	1.56	28.07	525.95	-	612.00
23	Phytoplankton	-	-	-	-	-	-	-	-	0.01	0.40	0.13	13.85	3.38	0.28	-	0.10	0.34	48.56	0.80	7.51	374.05	3000.00	645.60
24	Detritus	-	0.00	0.02	0.01	-	-	0.08	-	0.61	7.79	0.33	1.66	1.11	1.39	0.46	4.75	8.14	296.24	780.82	4.32	-	-	-
	Imports	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
	Sum	0.24	0.11	0.13	0.64	0.52	8.54	1.52	5.59	1.78	15.12	4.92	15.52	11.39	47.35	2.03	15.86	15.60	475.00	800.00	100.00	900.00	3000.00	2005.52

Table. Estimated Niche (prey) overlap index (Pianka overlap index) in the Karnataka model. Dashes indicate no overlap and values of 0.00 indicate an overlap < 0.0. Overlaps > 0.5 are in bold

	Group Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Marine Mammals	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Sharks	0.32	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Skates & Rays	0.39	0.26	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Large Pelagics	0.40	**0.79**	0.50	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Tunas	**0.77**	0.32	0.17	0.20	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Cephalopods	**0.84**	0.35	0.43	0.43	**0.83**	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Large Benthopelagics	0.50	0.41	0.30	**0.57**	0.36	0.43	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Large Benthic Carnivores	**0.61**	0.60	0.46	**0.60**	**0.59**	**0.76**	**0.60**	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Medium Benthic Carnivores	0.03	0.07	0.21	0.11	0.00	0.01	0.35	0.18	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Small Benthic Carnivores	0.02	**0.06**	0.27	0.10	0.00	0.01	0.24	0.08	**0.82**	1.00	-	-	-	-	-	-	-	-	-	-	-	-
11	Small Benthopelagics	**0.51**	0.33	0.38	0.35	**0.56**	**0.70**	**0.55**	**0.79**	**0.55**	0.34	1.00	-	-	-	-	-	-	-	-	-	-	-
12	Mackerel	0.00	0.00	0.03	0.01	0.00	0.00	0.01	0.00	0.07	0.14	0.07	1.00	-	-	-	-	-	-	-	-	-	-
13	Clupeids	0.00	0.00	0.06	0.02	0.00	0.00	0.15	0.07	**0.64**	0.48	0.43	**0.53**	1.00	-	-	-	-	-	-	-	-	-
14	Anchovies	0.01	0.00	0.02	0.01	0.00	0.00	0.08	0.05	**0.65**	0.35	0.38	0.01	**0.73**	1.00	-	-	-	-	-	-	-	-
15	Crabs & Lobsters	0.01	0.04	0.20	0.03	0.04	0.03	0.05	0.04	0.23	0.40	0.17	0.04	0.07	0.04	1.00	-	-	-	-	-	-	-
16	Shrimps	0.01	0.01	0.14	0.03	0.00	0.00	0.08	0.01	**0.81**	**0.67**	0.38	0.06	**0.65**	**0.81**	0.40	1.00	-	-	-	-	-	-
17	Benthic Omnivores	0.00	0.02	0.37	0.05	0.01	0.00	0.12	0.00	**0.61**	**0.86**	0.20	0.13	0.24	0.12	**0.69**	**0.59**	1.00	-	-	-	-	-
18	Heterotrophic Benthos	0.00	0.02	0.26	0.05	0.00	-	0.13	0.00	**0.67**	**0.93**	0.21	0.26	0.36	0.17	**0.54**	**0.62**	**0.93**	1.00	-	-	-	-
19	Meiobenthos	-	0.01	0.21	0.04	0.00	-	0.10	-	**0.54**	**0.80**	0.12	0.12	0.16	0.04	0.34	0.45	**0.78**	**0.89**	1.00	-	-	-
20	Micro Nekton	0.01	0.00	0.02	0.00	-	-	0.02	0.01	**0.57**	0.37	0.31	0.12	**0.78**	**0.97**	0.02	**0.78**	0.13	0.20	0.06	1.00	-	-
21	Large Zooplankton	-	-	-	-	-	-	-	-	0.01	0.21	0.06	**0.56**	**0.57**	0.23	-	0.02	0.02	0.14	0.00	0.41	1.00	-
22	Micro Zooplankton	-	-	-	-	-	-	-	-	0.01	0.04	0.05	**0.99**	0.48	0.01	-	0.01	0.03	0.14	0.00	0.11	**0.55**	1.00
23	Phytoplankton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table. Estimated Niche (predator) overlap index (Pianka overlap index) in the Karnataka mode. Dashes indicate no overlap and values of 0.00 indicate an overlap < 0.0. Overlaps > 0.5 are in bold

	Group Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Marine Mammals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Sharks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Skates & Rays	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Large Pelagics	-	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Tunas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Cephalopods	-	-	-	0.11	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Large Benthopelagics	-	-	-	**0.80**	-	0.22	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Large Benthic Carnivores	-	-	-	0.02	-	**0.69**	0.07	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Medium Benthic Carnivores	-	-	-	0.24	-	**0.73**	0.26	0.12	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Small Benthic Carnivores	-	-	-	0.06	-	**0.84**	0.11	**0.96**	0.33	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Small Benthopelagics	-	-	-	0.07	-	0.23	**0.61**	0.09	0.13	0.09	1.00	-	-	-	-	-	-	-	-	-	-	-	-
12	Mackerel	-	-	-	0.11	-	**0.56**	0.10	**0.95**	0.03	**0.85**	0.03	1.00	-	-	-	-	-	-	-	-	-	-	-
13	Clupeids	-	-	-	0.09	-	**0.68**	0.21	**0.92**	0.10	**0.90**	0.26	**0.87**	1.00	-	-	-	-	-	-	-	-	-	-
14	Anchovies	-	-	-	0.02	-	**0.89**	0.02	**0.83**	**0.52**	**0.93**	0.02	**0.66**	**0.74**	1.00	-	-	-	-	-	-	-	-	-
15	Crabs & Lobsters	-	-	-	0.04	-	**0.93**	0.18	0.45	**0.89**	**0.63**	0.28	0.33	0.43	**0.75**	1.00	-	-	-	-	-	-	-	-
16	Shrimps	-	-	-	0.00	-	**0.81**	0.03	**0.96**	0.29	0.99	0.07	**0.84**	**0.90**	**0.94**	**0.60**	1.00	-	-	-	-	-	-	-
17	Benthic Omnivores	-	-	-	0.07	-	**0.80**	0.15	0.36	**0.74**	**0.53**	0.15	0.22	0.32	**0.69**	**0.82**	**0.52**	1.00	-	-	-	-	-	-
18	Heterotrophic Benthos	-	-	-	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.00	-	-	-	-	-
19	Meiobenthos	-	-	-	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.01	**0.94**	1.00	-	-	-	-
20	Micro Nekton	-	-	-	0.00	-	0.09	0.02	0.04	0.09	0.07	0.04	0.00	0.02	0.11	0.10	0.07	0.23	0.06	0.01	1.00	-	-	-
21	Large Zooplankton	-	-	-	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.43	0.42	**0.54**	1.00	-	-
22	Micro Zooplankton	-	-	-	-	-	0.00	-	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.02	0.06	1.00	-
23	Phytoplankton	-	-	-	-	-	0.00	-	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.01	0.12	1.00

Table. Electivity (selection) index of different groups indicating a predator's preference for prey. It scales from -1 to 1; where -1 indicates total avoidance of a prey and 1 indicates total preference for a prey. Significant avoidance (> -0.8) and preference (>0.8) values are shown in bold

	Prey/Predator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	Marine Mammals																						
2	Sharks																						
3	Skates & Rays																						
4	Large Pelagics		**0.922**		0.787																		
5	Tunas																						
6	Cephalopods	0.654	0.307		0.276	**-0.976**	0.296	0.406	0.489	**-0.999**		-0.349											
7	Large Benthopelagics		0.716	-0.504	0.717			0.452															
8	Large Benthic Carnivores	0.240		-0.466	-0.505		0.501	-0.102	-0.436	**-0.999**		0.316											
9	Med Benthic Carnivores		-0.048		0.475			-0.209	0.455	**-1.000**													
10	Small Benthic Carnivores	0.726	**-0.865**	**0.919**	0.096	**-0.923**	0.547	0.006	0.158	**-0.979**	**-1.000**	0.418											
11	Small Benthopelagics	**-0.961**	**-0.930**	0.197	-0.364	0.491		0.674	**-0.931**		**-1.000**												
12	Mackerel				0.322		0.561	-0.637	**-0.992**														
13	Clupeids	0.382	0.211	-0.674	-0.004	**0.886**	0.363	0.302	-0.726	**-0.993**		-0.632											
14	Anchovies	-0.403	-0.334	0.508	-0.443	0.511	0.507	**-0.929**	0.480	**-0.992**	**-0.999**	0.703	**-1.000**	**-0.998**		**0.853**							
15	Crabs & Lobsters			0.599	0.127		0.358	0.743	0.796	**-0.989**	**-0.997**	**-0.918**											
16	Shrimps	**0.811**	-0.729	-0.778	**-0.842**	**0.840**	0.735	0.068	0.408	**-0.962**	**-0.995**	0.728		**-0.999**	**-1.000**	-0.065		**-0.999**					
17	Benthic Omnivores	0.591	0.242	0.453	0.209	-0.454	-0.037	0.336	0.619	0.686	0.764	0.359		**-1.000**	**-0.999**		**-0.999**	**-0.999**					
18	Heterotrophic Benthos		**-0.999**	**-0.831**				**-1.000**	**-0.999**	**-0.972**	**-0.962**	**-0.998**		**-0.992**	**-0.953**	-0.034	**-0.924**	0.206	-0.775				
19	Meiobenthos		**-0.997**			**-0.990**				**-0.982**	-0.673	**-0.907**			**-0.922**	**0.827**	-0.006	0.542	0.289	-0.626			
20	Micro Nekton			**-0.831**	**-0.835**			0.293	0.235	**0.942**	**0.882**	0.767		**0.939**	**0.902**		0.454				0.330		
21	Large Zooplankton	**-0.982**	**-1.000**					**-0.997**		0.589	0.461	-0.090	**-1.000**	**0.816**	**0.908**		**0.959**	0.563	0.664		**0.971**		
22	Micro Zooplankton									**-0.944**	0.025	**-0.945**	**-0.959**	0.178	0.159		-0.785	**-0.973**	0.003	**-0.919**	0.586	**0.989**	
23	Phytoplankton									**-0.994**	**-0.933**	**-0.978**	**0.936**	-0.385	**-0.986**		**-0.975**	**-0.816**	-0.411	**-0.993**	-0.738	0.473	**1.000**
24	Detritus		**-0.994**	-0.611	**-0.977**			**-0.911**		0.254	0.677	-0.700	**0.891**	-0.031	-0.640	0.775	0.655	**0.958**	**0.961**	**0.999**	-0.285		

Input Data Appendices

Diet Content Tables

GROUP 1 - MARINE MAMMALS

Diet of Dolphin *Tursiops truncatus*	
Food contents	Proportion
Saurida tumbil	0.1726
Squid	0.0407
Prawns	0.0542
Nemipterus mesoprion	0.1673
Anchovy	0.0122
Carangid	0.3163
Copepod	0.0005
Acetes	0.1214
Squilla	0.0347
Fish bones/Fish remains	0.0555
Thryssa	0.0246
Sum	1.0000
No. of samples	2

GROUP 2 - SHARKS

Diet of *Carcharhinus limbatus*	
Food contents	Proportion
Sardinella longiceps	0.3188
M.cordyla	0.1478
Leiognathus spp.	0.0017
Secutor insidator	0.0166
Sciaenids	0.0876
Other carangids	0.1474
Other clupeids	0.0384
Fish remains	0.0747
Megalopa larvae	0.0001
Loligo spp.	0.1207
Octopus spp.	0.0392
Foraminiferans	0.0035
Mud	0.0035
Sum	1.0000
No. of samples	106

Diet of *Scoliodon laticaudus*	
Food contents	Proportion
Sciaenids	0.4335
Anchovies	0.0700
Dig.carangids	0.0833
Dig.fish	0.2835
Loligo spp	0.1297
Sum	1.0000
No. of samples	13

Diet of *Sphyrna lewini*	
Food contents	Proportion
Cynoglossus spp	0.1027
S.jello	0.0637
C.dorab	0.0406
G.suppositus	0.0352
S.devisi	0.0667
Anchovies	0.0695
Dig.carangids	0.2192
Dig.fish	0.2943
S.choprai	0.0164
Loligo spp	0.0899
Parasite	0.0018
Sum	1.0000
No. of samples	76

Diet of *Rhizopriniodon acutus*	
Food contents	Proportion
Cynoglossus spp	0.1469
S.obtusata	0.0639
Anchovies	0.0315
Dig.carangids	0.3567
Dig.fish	0.1711
S.choprai	0.0203
Acetes spp	0.0086
Loligo spp	0.2009
Octopus spp	0.0244
Sum	1.0000
No. of samples	58

GROUP 3 - SKATES & RAYS

Diet of Devil rays – *Manta birostris*	
Food contents	Proportion
Acetes spp.	0.9234
Prawns	0.0018
Squilla	0.0068
Benthic crabs	0.0660
Silver bellies	0.0016
Molluscan pieces	0.0003
Sum	1.0000
No. of samples	2

Diet of *Dasyatis* spp.	
Food contents	Proportion
Saurida spp.	0.0130
Therapon spp.	0.1809
Nemipterus mesoprion	0.6224
Leiognathus spp.	0.0127
Ribbon fish	0.0013
Apogon spp.	0.0044
Lantern fish	0.0197
Acetes spp	0.1035
Prawn (Solenocera spp.)	0.0015
Digested matter	0.0406
Sum	1.0000
No. of samples	25

Diet of *Rhinobatos granulatus*	
Food contents	Proportion
Nemipterus mesoprion	0.0710
Trichiurus young ones	0.0014
Cynoglossus	0.0277
Anchovies digested	0.0216
other fishes (digested)	0.1075
Prawns digested	0.3548
Solenocera spp.	0.0785
Aristeus spp.	0.0185
M.affinis	0.0164
Acetes	0.2445
Crabs digested	0.0240
Squilla	0.0064
Digested matter	0.0277
Sum	1.0000
No. of samples	174

GROUP 4 - LARGE PELAGICS

Diet of *Sphyraena jello*	
Food contents	Proportion
Stolephorus spp.	0.2023
R.kanagurta	0.0270
Epinephelus (juv)	0.0053
Nemipterus spp.	0.1426
Leiognathus spp.	0.0161
Other soles	0.0554
Other carangids	0.3406
Other clupeids	0.0221
Other crabs	0.0117
Loligo spp.	0.1769
Sum	1.0000
No. of samples	150

Diet of *Scomberomorus commerson*	
Food contents	Proportion
Stolephorus spp.	0.2117
Sardinella longiceps	0.1260
M.cordyla	0.0647
R.kanagurta	0.0692
Tachysurus spp.	0.0084
Other Decapterus spp.	0.0474
Platycephalus (juv.)	0.0074
Saurida spp.	0.0011
C.kalla	0.0070
Therapon spp.	0.0019
Leiognathus spp.	0.0066
Other carangids	0.2886
Fish remains	0.1015
Solenocera spp.	0.0018
O.nepa	0.0040
Loligo spp.	0.0262
Octopus spp.	0.0235
Detritus	0.0030
Sum	1.0000
No. of samples	291

Diet of *Sphyraena obtusata*	
Food contents	Proportion
Stolephorus spp.	0.7768
Leiognathus spp.	0.0479
Other carangids	0.0369
Fish remains	0.1007
Other prawns	0.0130
Acetes spp.	0.0031
Loligo spp.	0.0119
Detritus	0.0097
Sum	1.0000
No. of samples	366

Diet of *Rachycenteron canadum*	
Food contents	Proportion
D. russeli	0.0322
Nemipterus	0.0957
P. hamrur	0.0078
G. suppositus	0.0279
Leiognathus sp	0.0013
S. insidiator	0.0024
Thryssa spp	0.0118
Anchovies	0.0176
T. lepturus	0.0583
Abalistes spp	0.1280
M. cordyla	0.0208
Therapon spp	0.0007
Puffer fish	0.0786
C. macrostoma	0.0063
Serranids	0.0257
R. kanagurta	0.0253
S. longiceps	0.0066
E. diacanthus	0.0294
S. devesi	0.0220
Bregmaceros	0.0005
L. lactarius	0.0049
Johneopsis	0.0023
D. acuta	0.0019
S. obtusata	0.0519
Saurida spp	0.0623
Eel	0.0005
Triglophorus spp	0.0016
Pseudorhombus spp	0.0017
Dactylopterid	0.0028
Clupeid fish	0.0132
Dig Carangid	0.0306
Dig fish	0.0138
S. crassicornis	0.0011
Prawns	0.0011
C. cruciata	0.0381
C. lucifera	0.0016
Other crabs	0.0343
O. nepa	0.1147
Loligo spp	0.0206
Sepia	0.0019
Dig matter	0.0002
Sum	1.0000
No. of samples	120

GROUP 5 - TUNAS

Diet of *Euthynnus affinis* Source Muthiah (1981)	
Food contents	Proportion
Fish remains	0.0282
Oil sardine	0.0394
Anchovy	0.0508
Digested fluids	0.0116
Squilla	0.0005
Acetes spp.	0.8328
Carangids	0.0104
Trematod worm	0.0026
Thryssa spp.	0.0137
Silver bellies	0.0017
Prawn	0.0016
C. kalla	0.0026
Pellona spp.	0.0039
Loligo spp.	0.0003
Sum	1.0000

Diet of *Auxis thazard* Source Muthiah (1981)	
Food contents	Proportion
Oil Sardine	0.4180
Digested matter	0.0299
Fish remains	0.1207
Caranx spp.	0.0233
Acetes spp.	0.0989
Anchovy	0.3091
Sum	1.0000

Diet of *Auxis rochei* Source Muthiah (1981)	
Food contents	Proportion
Fish remains	0.3406
Acetes	0.1734
Crustacean remains	0.0193
Digested matter	0.3947
Squilla	0.0093
Carangids	0.0116
Anchovy	0.0511
Sum	1.0000

GROUP 6-CEPHALOPODS
Source Oomen (1977)

Diet of *Loligo duvauceli*	
Food contents	Proportion
Nemipterus japonicus	0.1200
Saurida tumbil	0.1900
Stolephorus spp.	0.1600
Sardinella spp.	0.2330
Mackerel	0.0200
Metapenaeus spp.	0.0150
Penaeus spp.	0.1800
Squilla	0.0133
Crabs	0.0237
Loligo spp.	0.0450
Total	1.0000

GROUP 7 - LARGE BENTHOPELAGICS

Diet of *Scombroides tol*	
Food contents	Proportion
S.devisi	0.5246
S.bataviensis	0.0309
Stolephorus spp.	0.0894
Sardinella longiceps	0.0298
R.kanagurta	0.0076
Saurida spp.	0.1224
Other carangids	0.0445
Fish remains	0.0296
Solenocera spp.	0.0002
Metapenaeus spp.	0.0015
Other prawns	0.0083
Acetes spp.	0.0878
O.nepa	0.0065
Megalopa larvae	0.0006
Loligo spp.	0.0040
Detritus	0.0123
Sum	1.0000
No. of samples	46

Diet of catfishes Tachysurus spp	
Food contents	Proportion
S. longiceps	0.1020
S.bataviensis	0.0377
S. buccaneri	0.0326
S.devesi	0.0743
N. japonicus	0.0677
Spyraena obtusata	0.0153
Saurida spp.	0.0297
S.insidiator	0.0793
Ribbon fish	0.0196
M.cordyla	0.0328
D.russeli	0.0050
Cynoglossus spp.	0.0701
Uranoscopid	0.0122
Mene maculata	0.0114
Puffer fish	0.0162
Digested fish remains	0.0125
Acetes	0.0035
Solenocera spp.	0.0006
Parasite	0.0002
Squilla	0.0602
Carangid	0.0801
Octopus	0.0378
Crab	0.1193
Squid	0.0795
Cuttle fish	0.0005
Sum	1.0000
No. of samples	34

Diet of *Megalaspis cordyla*	
Food contents	Proportion
S.devisi	0.0407
S.bataviensis	0.1220
Stolephorus spp.	0.4134
Sardinella longiceps	0.0290
Decapterus spp.	0.1428
Platycephalus (juv.)	0.0093
Nemipterus spp.	0.0020
Leiognathus spp.	0.0031
Sciaenids	0.0104
Bregmaceros spp.	0.0007
Other carangids	0.0110
Fish remains	0.0820
Other prawns	0.0021
Acetes spp.	0.0817
O.nepa	0.0245
Loligo spp.	0.0202
Detritus	0.0051
Sum	1.0000
No. of samples	337

Diet of *Chirocentrus dorab*	
Food contents	Proportion
Stolephorus devesi	0.8543
S.batavensis	0.0325
S.buccaneri	0.0307
Digested anchovy	0.0744
Silver belly	0.0008
Fish scales	0.0032
Fish Young ones	0.0012
Digested matter	0.0029
Sum	1.0000
No. of samples	193

Diet of *Trichiurus lepturus*	
Food contents	Proportion
Stolephorus spp.	0.3662
Sardinella longiceps	0.0367
Other Decapterus spp.	0.1945
Saurida spp.	0.0366
Trichiuris lepturus	0.0816
Other carangids	0.0507
Fish remains	0.0368
Solenocera spp.	0.0032
Trachypenaeus spp.	0.0059
Penaeid prawns	0.0051
Acetes spp.	0.1207
Loligo spp.	0.0444
Detritus	0.0176
Sum	1.0000
No. of samples	732

GROUP 8 - LARGE BENTHIC CARNIVORES

Diet of *Epinephelus diacanthus*	
Food contents	Proportion
Anchovy	0.0161
Trichiurus spp.	0.0465
Saurida spp.	0.0006
Lutjanus spp.	0.0858
N.japonicus	0.0477
Platycephelus spp	0.0335
Silver belly	0.0060
Eel	0.0079
Soles	0.0351
Digested fish	0.1186
Solenocera spp.	0.0279
Trachypenaeus spp.	0.0339
M. monoceros	0.0180
Prawn appendages	0.0180
Hippa	0.0007
Acetes spp.	0.0134
Crabs	0.2752
Squilla	0.1098
Squid	0.0565
Cuttle fish	0.0140
Shell pieces	0.0006
Digested matter	0.0343
Sum	1.0000
No. of samples	637

Diet of *Pristipomoides filamentosus*	
Food contents	Proportion
Dactyloptena spp.	0.0309
Grammoplites spp.	0.2606
Soles: Synaptura spp.	0.0730
Platycephelus spp (Juv)	0.0206
Serranid fish	0.0105
Apogon spp.	0.0745
Nemipterus spp.	0.0935
Fish scales	0.0133
Solenocera spp.	0.1801
Digested prawn	0.0477
Digested matter	0.0100
Octopus	0.1854
Sum	1.0000
No. of samples	139

Diet of *Saurida undosquamis* Source Muthiah (1994)	
Food contents	Proportion
Stolephorus devisi	0.3558
Stolephorus spp.	0.0032
Nemipterus spp.	0.0175
Saurida spp.	0.0128
Platycephelus spp.	0.0034
Cynoglossus spp.	0.0009
Fish remains	0.3343
Loligo spp.	0.2607
Prawns	0.0007
Squilla	0.0003
Sardinella spp.	0.0002
Mackerel	0.0002
Decapterus spp.	0.0012
Caranx spp.	0.0000
Leiognathus spp.	0.0010
Upeneus spp.	0.0000
Barracuda	0.0002
Lactarius lactarius	0.0076
Sum	1.0000

Diet of *Saurida tumbil* Source Muthiah (1994)	
Food contents	Proportion
Stolephorus devisi	0.3664
Stolephorus spp.	0.0047
Nemipterus spp.	0.0020
Saurida spp.	0.0006
Platycephelus spp.	0.0003
Cynoglossus spp.	0.0003
Fish remains	0.3106
Loligo spp.	0.2824
Prawns	0.0001
Squilla	0.0001
sardinella spp.	0.0213
Decapterus spp.	0.0005
Caranx spp.	0.0015
Leiognathus spp.	0.0015
Upeneus spp.	0.0044
Apogon spp.	0.0025
Epinephelus spp.	0.0005
Lactarius lactarins	0.0005
Sum	1.0000

GROUP 9 - MEDIUM BENTHIC CARNIVORES

Diet of *Johnieops sina*	
Food contents	Proportion
Anchovy	0.0090
Bregmeceros	0.0075
Fish digested	0.1778
Fish Scales (Cycloid)	0.0123
Scales (Ctenoid)	0.0000
Acetes	0.2077
Metapenaeus spp.	0.0107
P. stylifera	0.0466
Solenocera spp.	0.0284
Prawn digested	0.0025
Squilla	0.4526
Bivalves	0.0001
Diatoms	0.0001
Jelly fish	0.0051
Mysis	0.0056
Lucifer	0.0003
Copepods	0.0012
Crustacean appendages	0.0064
Crab	0.0135
Evadne	0.0000
Gastropods	0.0014
Shells	0.0026
Digested fluid	0.0014
Polychaete worms	0.0004
Foraminiferans	0.0001
Nematode worms	0.0000
Digested matter	0.0066
Sum	1.0000
No. of samples	477

Diet of *Formio niger*	
Food contents	Proportion
Fish digested	0.1472
Squid	0.1635
Detritus	0.1179
Copepod	0.2565
Copepod appendages	0.1572
Coscinodiscus	0.0016
Fish Scales (Cycloid)	0.0006
Fish Scales (Ctenoid)	0.0000
Nauplii (larvae)	0.0010
Mysis spp.	0.0529
Crustacean appendages	0.0933
(Chelate legs)	
Amphipod	0.0081
Sum	1.0000
No. of samples	139

Diet of *Priacanthus hamrur*	
Food contents	Proportion
Anchovies	0.0336
Leiognathus spp.	0.0161
Saurida spp.	0.0262
Soles	0.0041
Digested fish	0.1602
Solenocera spp.	0.0307
Prawn	0.0243
Prawn digested	0.0099
Digested matter	0.1161
Crab	0.0197
Crab digested	0.0369
Acetes spp.	0.4543
Crustacean remains	0.0028
Squid	0.0576
Squilla	0.0074
Sum	1.0000
No. of samples	247

Diet of *Grammoplites suppositus*	
Food contents	Proportion
Anchovy	0.0009
Cynoglossus spp.	0.0162
Trichiurus spp.	0.0176
Silver bellies	0.0087
Nemipterus spp.	0.0979
Platycephalus spp.	0.0074
Saurida spp.	0.0081
Other Fish (juveniles)	0.0182
Fish remains	0.0159
Digested fish	0.1078
Solenocera spp.	0.1194
Trachypenaeus spp.	0.0430
M. monoceros	0.0135
Other prawns	0.0755
Digested prawns	0.1190
Acetes spp.	0.0205
Charybdis spp.	0.1176
Hippa spp.	0.0045
Digested crab	0.0793
O. nepa	0.0740
Loligo spp.	0.0159
Sea urchin spines	0.0019
Detritus	0.0170
Sum	1.0000
No. of samples	599

GROUP 9 - MEDIUM BENTHIC CARNIVORES

Diet of *Otolithes ruber*	
Food contents	Proportion
Anchovy	0.1008
Oil Sardine	0.1679
Soles (Cynoglossus spp.)	0.0047
N. mesoprion	0.2635
O.tardore	0.0059
Grammoplites spp.	0.0079
S.insidiator	0.0715
Bregmaceros	0.0075
Cat fishes (Plotosidae)	0.0013
Digested fish	0.0284
Other Fish	0.0021
Acetes	0.1191
Parapeneopsis stylifera	0.0098
Parapenaeus spp.	0.0030
M. monoceros	0.0162
M. affinis	0.0122
M. dobsoni	0.0506
Solenocera spp.	0.0204
Prawn digested	0.0386
Squilla	0.0551
Squid	0.0010
Digested matter	0.0126
Sum	1.0000
No. of samples	253

Diet of *Pseudorhombus natelensis*	
Food contents	Proportion
S.devesi	0.0021
Saurida spp.	0.0070
Lactarius lactarius	0.0114
Nemipterus mesoprion	0.0238
Fish Digested	0.8767
Acetes spp.	0.0004
Solenocera spp.	0.0493
Prawn digested	0.0106
Crab	0.0031
Squilla	0.0075
Isopod	0.0003
Sagitta spp.	0.0078
Sum	1.0000
No. of samples	90

Diets of *Pampus argenteus*	
Food contents	Proportion
Fish digested	0.0176
Squid	0.0259
Squid digested	0.0038
Detritus	0.4877
Copepod	0.0300
Copepod appendages	0.0223
Copepod digested	0.3177
Coscinodiscus	0.0054
Crustacean appendages	0.0219
Crustacean larvae (Nauplius)	0.0092
Crustacean digested	0.0227
Squilla	0.0198
Amphipod	0.0067
Fish egg	0.0023
Decapod appendages	0.0002
Nitzchia	0.0039
Diatoms	0.0001
Polychaete worms	0.0019
Calanus spp.	0.0010
Sum	1.0000
No. of samples	190

Diet of *Pseudorhombus arsius*	
Food contents	Proportion
Stolephorus spp.	0.0601
Platycephalus (juv.)	0.0783
Saurida spp.	0.0138
Nemipterus spp.	0.1287
Therapon spp.	0.0928
Cynoglossus spp.	0.0265
Pseudorhombus spp.	0.0830
Other soles	0.0171
Trichiurus lepturus	0.0425
Eels	0.0169
Polynemus indicus	0.2117
Fistularia spp.	0.0086
Fish remains	0.0491
Solenocera spp.	0.0060
Metapenaeus spp.	0.0713
Other prawns	0.0232
Acetes spp.	0.0040
O.nepa	0.0007
Charybdis spp	0.0163
Lobster juv	0.0007
Loligo spp	0.0470
Neries spp.	0.0014
Detritus	0.0003
Sum	1.0000
No. of samples	322

GROUP 10- SMALL BENTHIC CARNIVORES

Diet of *N. japonicus* Source Zacharia (unpubl)	
Food contents	Proportion
Squilla	0.2838
Crabs	0.1364
Prawn	0.1339
Eel juveniles	0.0015
Other teleosts	0.0661
Cephalopods	0.0284
Amphipods	0.0040
Polychaetes	0.0037
Digestev fish	0.0032
Dig.matter	0.3390
Sum	1.0000

Diet of *Nemipterus mesoprion* Source Zacharia (2003)	
Food contents	Proportion
Acetes spp.	0.2537
Prawns	0.2836
Crabs	0.0821
Squids	0.1045
Anchovies	0.0896
Saurida spp.	0.0448
Lactarius lactaries	0.0224
Platycephalus	0.0224
Nemipterus spp.	0.0075
Leiognathus spp.	0.0075
Detritus	0.0821
Sum	1.0000

Diet of *Lactarius lactarius*	
Food contents	Proportion
Stolephorus spp	0.4142
Dig fish matter	0.2017
Acetes spp.	0.2742
Shrimps	0.0484
O. nepa	0.0270
Benthic crabs	0.0019
Mysids	0.0000
Leiognathus spp	0.0010
Bregmaceros	0.0036
L. lactarius	0.0009
Trichiurus	0.0031
Other fishes	0.0203
Gastropods	0.0000
Loligo spp.	0.0008
Decapod larva	0.0006
Detritus	0.0021
Echinoderms	0.0001
Sum	1.0000
No. of samples	331

Diet of *Secutor insidiator*	
Food contents	Proportion
Sand	0.0037
Detritus	0.2674
Foraminiferans	0.0037
Nitzchia	0.0048
Coscinodiscus	0.0088
Scales	0.0045
Copepods (Small)	0.3156
Crustacean appendages	0.0928
Pleurosigma	0.0017
Neries	0.0108
Mysis	0.1028
Diatoms	0.0153
Thallasirothrix	0.0060
Fish egg	0.0109
Sagitta	0.0406
Lucifer	0.0850
Amphipods	0.0153
Cladocerans	0.0053
Tintinnids	0.0009
Fragilaria	0.0041
Sum	1.0000
No. of samples	203

Diet of *Leiognathus bindus*	
Food contents	Proportion
Copepod	0.1223
Copepod appendages	0.0256
Crust appendages	0.0212
Fish egg	0.0133
Cosinodiscus	0.0034
Detritus	0.6801
Mysis	0.0036
Diatoms	0.0014
Neries	0.0653
Nitzchia	0.0023
Thallasiothrix	0.0019
Sand	0.0328
Formaniferans	0.0133
Scales (Cycloid)	0.0012
Scales (Ctenoid)	0.0029
Pleurosigma	0.0012
Lucifer appendages	0.0026
Diatoms	0.0004
Tintinnid	0.0002
Polychaete worms	0.0035
Flavella	0.0003
Fragilaria	0.0013
Sum	1.0000
No. of samples	105

GROUP 11 - SMALL BENTHOPELAGICS

Diet of *Caranx kalla*	
Food contents	Proportion
Acetes spp.	0.6700
Fish juveniles	0.0087
Fish digested	0.1220
Squilla digested	0.0391
Copepods	0.0109
Copepod appendages	0.0252
Crustacean appendages	0.0225
Cladocerans	0.0119
Coscinodiscus	0.0081
Forameniferans	0.0183
Evadne	0.0026
Nauplii (Prawn)	0.0012
Lucifers	0.0194
Mysis	0.0062
Fish eggs	0.0055
Clam	0.0008
Detritus/Digested matter	0.0277
Sum	1.0000
No. of samples	319

Diet of *Decapterus macrosoma*	
Food contents	Proportion
Anchovies	0.0250
Fish Scales	0.1982
Fish digested	0.3923
Squilla	0.1321
Acetes	0.2524
Sum	1.0000
No. of samples	140

Diet of *Decapterus russelli*	
Food contents	Proportion
Anchovies	0.2810
Clupeids	0.0094
Leiognathus spp.	0.0595
S. insidiator	0.0625
Saurida spp.	0.1866
Lutjanus spp.	0.0022
Nemipterus spp.	0.0196
Ribbon fish (Juvenile)	0.0017
Soles	0.0012
Bregmeceros	0.0082
Therapon spp.	0.0020
Serranid young ones	0.0002
Digested fish	0.0738
Fish remains (Scales)	0.0350
P. stylifera	0.0043
Solenocera spp.	0.0033
Acetes spp.	0.2293
Crab	0.0006
Leptocephalus larvae	0.0004
Squilla	0.0029
Squid	0.0137
Cuttle fish	0.0003
Foraminiferans	0.0009
Digested matter	0.0015
Sum	1.0000
No. of samples	616

GROUP 12 - MACKEREL

Diet of Mackerel – *Rastrelliger kanagurta* Source Prathiba (unpubl)	
Food contents	Proportion
Diatoms	0.8870
Dinoflagellates	0.0034
Tintinnids	0.0003
Bivalve larvae	0.0001
Copepod eggs	0.0010
Copepod nauplii	0.0007
Cypris larvae	0.0002
Cladocerans	0.0004
Other zooplankton	0.0001
Fish scales	0.0003
Sand	0.1067
Sum	1.0000
No. of samples	

GROUP 13-CLUPEIDS

Diet of *Sardinella longiceps* Source Prathiba (unpubl)	
Food contents	Proportion
Diatoms	0.3361
Dinoflagellates	0.0603
Tintinnids	0.0650
Copepods	0.3560
Larval forms	0.0664
Other zooplanktons	0.1162
Sum	1.000

Diet of *Sardinella gibbosa*	
Food contents	Proportion
Copepods	0.6340
Rhizosolenia spp	0.0610
Chaetoceros spp	0.0250
Bacteriastrum spp	0.0160
Pleurosigma spp	0.1520
Thalassiothrix spp	0.1120
Sum	1.0000
No. of samples	25

Diet of *Thryssa mystax*	
Food contents	Proportion
Bregmeceros	0.1455
Anchovies	0.0842
Sciaenid young ones	0.0809
Serranids young ones	0.0672
Fish digested	0.1555
Fish Scales	0.0230
Fish eggs	0.0048
P.stylifera	0.0421
M.dobsoni	0.0092
Solenocera spp.	0.0522
Acetes spp.	0.0994
Prawns dig	0.1148
Calanus spp	0.0095
Rhizosolenia	0.0017
Pleurosigma	0.0000
Copepods	0.0208
Copepods appendages	0.0002
Zoea of crab	0.0013
Lucifers	0.0031
Mysis	0.0126
Segments of Prawns	0.0187
Squilla	0.0300
Digested crustaceans	0.0105
Sagitta	0.0011
Detritus	0.0118
Sum	1.0000
No. of samples	443

GROUP 13 - CLUPEIDS

Diet of *Dussumeria acuta*	
Food contents	Proportion
Fish eggs	0.0070
Fish juveniles	0.1567
Anchovy	0.3719
Fish Scales	0.0018
Silver bellies	0.0181
Prawn appendages	0.0003
Squids	0.0480
Copepods	0.0352
Lucifer	0.1546
Megalopa	0.0043
Mysis	0.0171
Crustacean larvae	0.0001
Amphipods	0.0001
Crustacean appendage	0.0172
Decapod digested	0.0025
Nauplius	0.0047
Evadne	0.0327
Chaetoceros	0.0005
Coscinodiscus	0.0017
Nitzchia	0.0004
Plant matter	0.0306
Detritus	0.0946
Sum	1.0000
No. of samples	439

Diets *Esculosa thoracata*	
Food contents	Proportion
Coscinodiscus	0.0198
Nauplii larvae	0.1877
Copepod	0.1329
Small Copepods	0.1168
Copepod appendages	0.1585
Amphipod	0.0047
Digested decapods	0.0006
Diatom	0.0050
Mysis	0.0106
Mysis appendages	0.0062
Detritus	0.1845
Fish egg	0.0112
Microstella	0.0048
Cypris	0.0055
Fish scales (Cycloid)	0.0001
Fish scales (Ctenoid)	0.0001
Cladocerans	0.0075
Zoea of crab	0.0097
Nitzchia	0.0175
Veliger larvae	0.0108
Lucifer	0.0968
Chaetoceros	0.0045
Megalopa	0.0043
Sum	1.0000
No. of samples	323

GROUP 14 - ANCHOVIES

Diet of *Stolephorus devisi*

Food contents	Proportion
Tintinid	0.0003
Copepod	0.0997
Copepod appendages	0.2963
Isopod	0.0060
Crustacean appendages	0.0718
Digested matter	0.3610
Scales (Cycloid)	0.0019
Cladoceran	0.0347
Fish Eggs	0.0033
Skeletonema	0.0001
Clam/ Bivalve	0.0127
Alima larvae	0.0047
Zoea	0.0019
Prawn nauplii	0.0010
Diatom	0.0015
Mysis sp.	0.0235
Mysis appendages	0.0727
Lucifer	0.0002
Nitzchia	0.0027
Coscinodiscus	0.0006
Polychaete	0.0032
Sum	1.0000
No. of samples	62

Diet of *Stolephorus commersoni*

Food contents	Proportion
Squid	0.1128
Digested matter	0.0751
Cladoceran	0.0588
Mysis	0.2291
Mysis appendages	0.1361
Prawn	0.0163
Prawn larvae	0.0235
Eggs	0.0041
Crustacean appendages	0.0564
Fish (Flat Head)	0.0248
Fish digested (Bones)	0.1293
Copepod	0.0132
Copepod appendages	0.0065
Detritus	0.0174
Squilla	0.0007
Alima larvae	0.0105
Fish Scales (Ctenoid)	0.0030
Isopods	0.0051
Clam	0.0119
Polychaete worms	0.0035
Cypris	0.0310
Foraminiferans	0.0309
Sum	1.0000
No. of samples	160

Diet of *Stolephorus waitei*

Food contents	Proportion
Copepod	0.0308
Copepod appendages	0.1023
Mysis	0.1244
Mysis appendages	0.2082
Nitschia	0.0039
Fish digested	0.3022
Digested matter	0.0820
Isopods	0.0045
Diatoms	0.0027
Cladoceran	0.0615
Crustacean appendages	0.0113
Prawn	0.0662
Sum	1.0000
No. of samples	64

Diet of *Stolephorus indicus*

Food contents	Proportion
Cladocerans	0.0672
Alima larva	0.0183
Copepods	0.0193
Digested matter	0.1121
Copepods appendages	0.0210
Mysis	0.0305
Mysis appendages	0.0915
Fish digested	0.1265
Flat fish	0.3602
Squid digested	0.1510
Bivalve larva	0.0025
Sum	1.0000
No. of samples	54

GROUP 15 - CRABS & LOBSTERS

Diet of *Portunus pelagicus* Source Sukumaran (1999)	
Food contents	Proportion
Crustaceans	0.5477
Fish	0.3060
Molluscs	0.0207
Polychaetes	0.0909
Debris	0.0347
Sum	1.0000

Diet of *Portunus sanguinolentus* Source Sukumaran (1999)	
Food contents	Proportion
Crustaceans	0.4752
Fish	0.3983
Molluscs	0.0189
Polychaetes	0.0786
Debris	0.0290
Sum	1.0000

GROUP 16 - SHRIMPS

Diet of *M. monoceros*	
Food contents	Proportion
Crustacean appendages	0.6574
Polychaete appendages	0.0335
Scales	0.0057
Coscinodiscus	0.0034
Cypris	0.0001
Polychate worms	0.0297
Forameniferans	0.0140
Detritus	0.1869
Neries	0.0003
Fish remains	0.0014
Spines	0.0016
Squid appendages	0.0101
Fish larvae	0.0117
Sand	0.0083
Fish scale	0.0028
Bivalve Shells	0.0020
Fish dig	0.0031
Pleurosigma	0.0004
Diatoms	0.0002
Polychaete segments	0.0228
Fish bones	0.0005
Shell	0.0043
Sum	1.0000
No. of samples	255

GROUP 17 - BENTHIC OMNIVORES

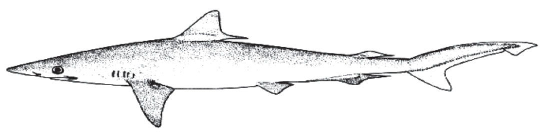
Diet of *Cynoglossus macrostomus*	
Food contents	Proportion
Fish Scales	0.0318
Forameniferans	0.0563
Diatom	0.0055
Detritus	0.3932
Shells	0.1761
Polychaete tubes	0.0512
Sand and mud	0.0308
Mysis digesetd	0.0250
Copepod appendages	0.0309
Cosinodiscus	0.0007
Polychaete worms	0.0469
Nitzchzia	0.0006
Crustacean appendages	0.0456
Fins fish	0.0034
Fish dig matter	0.0496
Spicules	0.0080
Non detritus	0.0016
Squilla dig	0.0085
Prawn appendages	0.0109
Amphipods	0.0031
Conus spp. (shells)	0.0064
Fish egg	0.0014
Prawn/ mysis dig	0.0126
Pleurosigma	0.0001
Sum	1.0000
No. of samples	320

Diet of *Oratosquilla nepa*	
Food contents	Proportion
Polychaete worms	0.0184
Crustacean appendage	0.1331
Detritus	0.2432
Sand	0.1687
Polychaete segment	0.0915
Polychaete apendage	0.0731
Foraminifera	0.0403
Gastropod Shell	0.1529
Asterionella	0.0016
Fish scale	0.0138
Mysis head	0.0016
Cosinodiscus	0.0020
Mysis eye	0.0117
Scales	0.0020
Fish eye	0.0002
Fish egg	0.0032
Nitzchia	0.0228
Fish digested	0.0121
Clam	0.0005
Diatom	0.0050
Polychaete tube	0.0009
Cladocera	0.0014
Sum	1.0000
No. of samples	109

Species Life History Sheets

Species Life History Sheet

Species Name : *Rhizoprionodon acutus* Common Name : Milk shark (Thatte) Family : Carcharhinidae	Centre : Mangalore + Malpe
	Period : 1999 - 2001
	Gears Exploiting : GN
	Fleet : DGN
	Habitat Area : 27000 km^2
	Ecological Grouping : 2. Sharks
	Data Source : **Project**
	Annual Ave Catch : 100 t



Growth Parameters

L_{max}/t_{max}	87.5
L_r	27.5
L'	45.5
L_{mean}	59.2
L_∞	96.0
K	0.81 yr^{-1}
ϕ'	3.873
W_∞	4226 g
t_0	-0.0167

LW Parameters

	Male	Female	Combined
a			0.0027
b			3.125
r			0.98
n			41

ELEFAN Parameters

File Name	Racutasm.lfq
R_n	0.262
SS/SL	3 / 35.0

Selection Parameters	
L-25	26.0
L-50	32.0
L-75	39.0
L_c / L_∞	0.33
t_c	0.5 yr

Maturity Parameters	
L_m	50.3 cm
Peak breeding	
L_m / L_∞	0.52
Generation time (t_g=t_{opt})	1.36 yr

Population Parameters

Z	2.16
CI of Z	2.02-2.29
M	1.15
F	1.01
E (F/Z)	0.47
L_{opt}	65.2
F_{opt}	1.02
Recruit Period	Mar-Apr

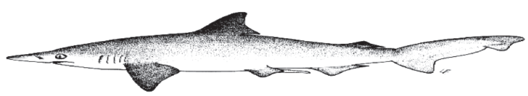
Ecopath Parameters

P/B	2.16
Q/B	7.15
Ar	1.61
Biomass	213 t
EE	0.24
Feeding type	Carnivore
Trophic level	4.45

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Scoliodon laticaudus* Common Name : Spade nose shark Family : Carcharhinidae	Centre : Mangalore + Malpe
	Period : 2000-01
	Gears Exploiting : **GN**
	Fleet : DGN
	Habitat Area : 27000 km^2
	Ecological Grouping : 2. Sharks
	Data Source : **Project**
	Annual Ave Catch : 71 t



Growth Parameters

L_{max}/t_{max}	92.0
L_r	34.0
L'	45.0
L_{mean}	57.0
L_∞	118.0
K	0.45 yr^{-1}
φ'	3.797
W_∞	4965 g
t_0	-0.0373

LW Parameters

	Male	Female	Combined
a			0.0102
b			2.745
r			0.84
n			37

ELEFAN Parameters

File Name	Scolio.lfq
R_n	0.295
SS/SL	2 / 70

Selection Parameters

L-25	30.0
L-50	36.0
L-75	41.0
L_c/L_∞	0.31
t_c	0.77 yr

Maturity Parameters

L_m	60.6
Peak breeding	Mar, Sep-Dec
L_m/L_∞	0.51
Generation time (t_g=t_{opt})	2.3 yr

Population Parameters

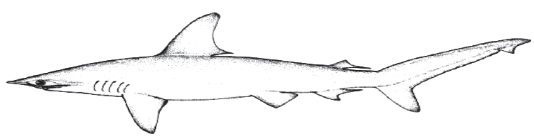
Z	2.5
CI of Z	1.95-3.04
M	0.74
F	1.76
E (F/Z)	0.7
L_{opt}	76.2
F_{opt}	1.73

Ecopath Parameters

P/B	2.5
Q/B	6.22
Ar	1.05
Biomass	101 t
EE	0.24
Feeding type	Carnivore
Trophic level	4.45

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sphyrna lewini* Common Name : Hammer headed shark Family : Sphyrnidae	Centre : Mangalore + Malpe
	Period : 1999-2000
	Gears Exploiting : **GN**
	Fleet : DGN
	Habitat Area : 27000 km^2
	Ecological Grouping : 2 Sharks
	Data Source : **Project**
	Annual Ave Catch : 292 t

Growth Parameters

L_{max}/t_{max}	115.0
L_r	43.5
L'	60.0
L_{mean}	73.0
L_∞	156.0
K	0.51 yr^{-1}
ϕ'	4.0938
W_∞	42577 g
t_0	-0.0299

LW Parameters

	Male	Female	Combined
a			0.0238
b			2.851
r			0.92
n			43

ELEFAN Parameters

File Name	Slewsm80, 81, 82. lfq (3 files)
R_n	0.387
SS/SL	12 / 60

Selection Parameters	
L-25	39.0
L-50	43.0
L-75	50.0
L_c / L_∞	0.28
t_c	0.6 yr

Maturity Parameters	
L_m	77.8 cm
Peak breeding	
L_m / L_∞	0.5
Generation time (t_g=t_{opt})	2.2 yr

Population Parameters

Z	3.63
CI of Z	3.21-4.06
M	0.74
F	2.89
E (F/Z)	0.8
L_{opt}	105
F_{opt}	3.0

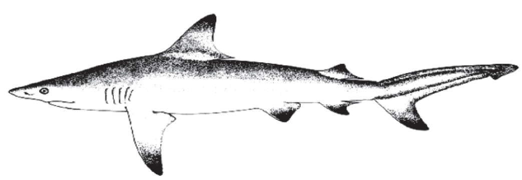
Ecopath Parameters

P/B	3.63
Q/B	4.18
Ar	1.26
Biomass	365 t
EE	0.24
Feeding type	Carnivore
Trophic level	4.45

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Carcharhinus limbatus*
Common Name : Black tip shark (Thate)
Family : Carcharhinidae



Centre : Mangalore	
Period : 2000-01	
Gears Exploiting : GN	
Fleet : DGN	
Habitat Area : 27000 km^2	
Ecological Grouping : 2. Sharks	
Data Source : Project	
Annual Ave Catch : 203 t	

Growth Parameters

L_{max}/t_{max}	103
L_r	56
L'	75
L_{mean}	82.9
L_∞	114
K	0.92 yr^{-1}
ϕ'	4.0776
W_∞	4001 g
t_0	-0.0122

LW Parameters

	Male	Female	Combined
a			0.221
b			2.07
r			0.66
n			20

ELEFAN Parameters

File Name	Climb80/81.lfq
R_n	0.322
SS/SL	1/ 62.5

Selection Parameters	
L-25	65
L-50	71
L-75	76
L_c/L_∞	0.622
t_c	1.048

Maturity Parameters	
L_m	58.7
Peak breeding	
L_m/L_∞	0.51
Generation time (t_g=t_{opt})	1.292 yr

Population Parameters

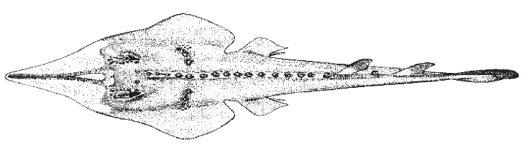
Z	4.81
CI of Z	3.56-6.06
M	1.19
F	3.62
E (F/Z)	0.75
L_{opt}	79.66
F_{opt}	3.57
Recruit period	May-Jul, Oct-Jan

Ecopath Parameters

P/B	4.81
Q/B	8.41
Ar	2.4
Biomass	270 t
EE	0.24
Feeding type	Carnivore
Trophic level	4.45

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Rhinobatos granulosus* Common Name : Granulated shovel nose ray Family : Rhinobatidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 3 Skates and Rays
	Data Source : **Project**
	Annual Ave Catch : 55 t

Growth Parameters

L_{max}/t_{max}	93.0
L_r	23.4
L'	
L_{mean}	
L_∞	97.8
K	0.28 yr^{-1}
φ'	3.428
W_∞	4722 g
t_0	-0.0589

LW Parameters

	Male	Female	Combined
a	0.0044	0.0049	0.00384
b	2.910	2.889	3.06
r	0.94	0.97	
n	89	85	

ELEFAN Parameters

File Name	Rgranulosm.lfq
R_n	0.3
SS/SL	6 / 94

Selection Parameters	
L-25	22.5
L-50	25.0
L-75	28.4
L_c / L_∞	0.26
t_c	0.3 yr

Maturity Parameters	
L_m	15.1
Peak breeding	
L_m / L_∞	0.52
Generation time (t_g=t_{opt})	4.7 yr

Population Parameters

Z	0.75
CI of Z	0.66-0.84
M	0.30
F	0.45
E (F/Z)	0.60
L_{opt}	72.1
F_{opt}	0.45

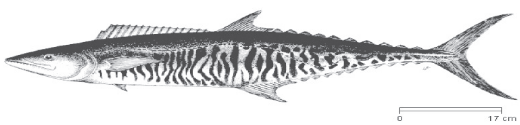
Ecopath Parameters

P/B	0.75
Q/B	5.96
Ar	0.77
Biomass	91 t
EE	0.98
Feeding type	Carnivore
Trophic level	3.59

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Scombermorus commerson* Common Name : Narrow barred seerfish Family : Scombridae	Centre : Mangalore
	Period : 1999 - 2000
	Gears Exploiting : **TR**, **GN**, **PS**
	Fleet : MDF, DGN, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 4 Large pelagics
	Data Source : **Other**
	Annual Ave Catch : 2555 t



Growth Parameters	
L_{max}/t_{max}	134.9
L_r	25.0
L'	
L_{mean}	
L_∞	142.0
K	0.66 yr^{-1}
ϕ'	4.1482
W_∞	17088 g
t_0	-0.0214

LW Parameters	Male	Female	Combined
a			0.01606
b			2.8
r			0.99
n			0.32

ELEFAN Parameters	
File Name	Muthiah data
R_n	
SS/SL	

Selection Parameters	
L-25	
L-50	62.6
L-75	70.3
L_c / L_∞	0.44
t_c	0.86 yr

Maturity Parameters	
L_m	71.5
Peak breeding	Jan-Sept
L_m / L_∞	0.5
Generation time (t_g=t_{opt})	1.8 yr

Population Parameters	
Z	5.33
CI of Z	
M	0.9
F	4.43
E (F/Z)	0.83
L_{opt}	97.6
F_{opt}	4.93

Ecopath Parameters	
P/B	5.33
Q/B	9.78
Ar	4.74
Biomass	3078 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Scombermorus guttatus* Common Name : Indo- Pacific seer fish Family : Scombridae	Centre : Mangalore
	Period : 1999 - 2000
	Gears Exploiting : **GN**, **PS**
	Fleet : GN, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 4 Large pelagics
	Data Source : **Other**
	Annual Ave Catch : 585 t

Growth Parameters		
L_{max}/t_{max}	51.0	
L_r	32.0	
L'		
L_{mean}		
L_∞	69.0	
K	0.8 yr^{-1}	
ϕ'	3.5681	
W_∞	2991 g	
t_0	-0.0187	

LW Parameters	Male	Female	Combined
a			0.0229
b			2.782
r			0.93
n			200

ELEFAN Parameters	
File Name	Muthiah data
R_n	
SS/SL	

Selection Parameters	
L-25	
L-50	40.7
L-75	43.3
L_c/L_∞	0.60
t_c	1.1 yr

Maturity Parameters	
L_m	37.4 cm
Peak breeding	
L_m/L_∞	0.54
Generation time (t_g=t_{opt})	1.3 yr

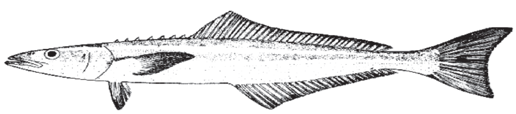
Population Parameters	
Z	6.00
CI of Z	
M	1.29
F	4.71
E (F/Z)	0.79
L_{opt}	44.9
F_{opt}	4.85

Ecopath Parameters	
P/B	6.00
Q/B	12.21
Ar	4.04
Biomass	740 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Rachycentron canadum* Common Name : King fish Family : Rachycentridae	Centre : Mangalore + Malpe
	Period : 1999-01
	Gears Exploiting : **TR**, **GN**, **PS**
	Fleet : MDF, DGN, PS
	Habitat Area : 27000km^2
	Ecological Grouping : 4. Large Pelagics
	Data Source : **Project**
	Annual Ave Catch : 350 t



Growth Parameters

L_{max}/t_{max}	162.5
L_r	26.0
L'	55.0
L_{mean}	87.4
L_∞	180.0
K	0.72 yr^{-1}
ϕ'	4.3679
W_∞	37838 g
t_0	-0.0174

LW Parameters

	Male	Female	Combined
a	0.0099	0.0042	0.00705
b	2.876	3.092	2.984
r	0.93	0.99	0.96
n	16	22	38

ELEFAN Parameters

File Name	Rachy.lfq
R_n	0.166
SS/SL	12 / 117

Selection Parameters	
L-25	27.0
L-50	50.0
L-75	73.0
L_c / L_∞	0.28
t_c	0.44 yr

Maturity Parameters	
L_m	88.5 cm
Peak breeding	
L_m / L_∞	0.49
Generation time (t_g=t_{opt})	1.68 yr

Population Parameters

Z	2.37
CI of Z	2.61-2.14
M	0.9
F	1.48
E (F/Z)	0.62
L_{opt}	127
F_{opt}	1.2

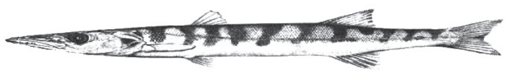
Ecopath Parameters

P/B	2.37
Q/B	4.06
Ar	0.99
Biomass	565 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sphyraena jello* Common Name : Pick handle barracuda Family : Sphyraenidae	Centre : Mangalore + Malpe
	Period : 1999-01
	Gears Exploiting : **TR**, **GN**, **PS**
	Fleet : MDF, DGN, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 4. Large Pelagics
	Data Source : **Project**
	Annual Ave Catch : 670 t



Growth Parameters

L_{max}/t_{max}	81.0
L_r	16.6
L'	42.0
L_{mean}	47.8
L_∞	68.9
K	0.71 yr^{-1}
ϕ'	3.5277
W_∞	2337 g
t_0	-0.0232

LW Parameters

	Male	Female	Combined
a	0.0052	0.0036	0.0044
b	3.059	3.170	3.1145
r	0.96	0.93	0.913
n	177	188	365

ELEFAN Parameters

File Name	Sjello2.lfq, sjellosm.lfq
R_n	0.136
SS/SL	4 / 63.0

Selection Parameters	
L-25	22.7
L-50	36.7
L-75	38.2
L_c / L_∞	0.53
t_c	1.1 yr

Maturity Parameters	
L_m	37.4
Peak breeding	
L_m / L_∞	0.54
Generation time (t_g=t_{opt})	1.45 yr

Population Parameters

S	S
Z	1.88
CI of Z	1.6-2.17
M	1.16
F	0.72
E (F/Z)	0.38
L_{opt}	44.6
F_{opt}	0.7

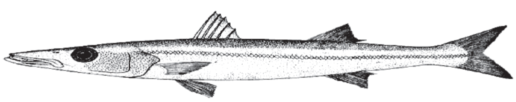
Ecopath Parameters

P/B	1.88
Q/B	9.79
Ar	2.62
Biomass	1764 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sphyraena obtusata*
Common Name : Obtuse barracuda
Family : Sphyraenidae



Centre : Mangalore	
Period : 1999-2000	
Gears Exploiting : **TR**	
Fleet : MDF	
Habitat Area : 27000 km^2	
Ecological Grouping : 4. Large pelagics	
Data Source : **Project**	
Annual Ave Catch : 838 t	

Growth Parameters

L_{max}/t_{max}	28.6
L_r	16.6
L'	22.0
L_{mean}	24.1
L_∞	32.2
K	1.2 yr^{-1}
ϕ'	3.0949
W_∞	217 g
t_0	-0.0089

LW Parameters

	Male	Female	Combined
a	0.0043	0.0044	
b	3.120	3.110	
r	0.94	0.96	
n	175	191	

ELEFAN Parameters

File Name	Obtusm.lfq
R_n	0.302
SS/SL	1/ 23.5

Selection Parameters

L-25	20.2
L-50	21.3
L-75	22.3
L_c/L_∞	0.66
t_c	0.9 yr

Maturity Parameters

L_m	18.9
Peak breeding	
L_m/L_∞	0.59
Generation time ($t_g=t_{opt}$)	0.84 yr

Population Parameters

Z	5.76
CI of Z	4.37-7.16
M	2.02
F	3.74
E (F/Z)	0.64
L_{opt}	20.6
F_{opt}	3.75

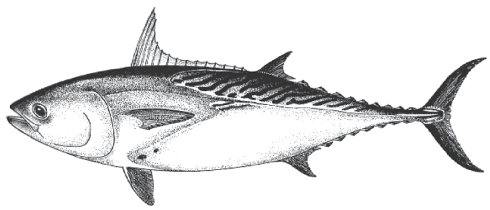
Ecopath Parameters

P/B	5.76
Q/B	16.43
Ar	2.79
Biomass	1289 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Euthynnus affinis*
Common Name : Little Tuna (Kedar)
Family : Scombridae



Centre : Mangalore	
Period : 2000-01	
Gears Exploiting : GN, PS.	
Fleet : DGN, PS	
Habitat Area : 27.000 km^2	
Ecological Grouping : 5. Tunas	
Data Source : Other	
Annual Ave Catch : 2001 t	

Growth Parameters

L_{max}/t_{max}	68
L_r	19.5
L’	37
L_{mean}	45.9
L_∞	89
K	0.9 yr^{-1}
ϕ’	3.853
W_∞	8745 g
t_0	-0.0137

LW Parameters

	Male	Female	Combined
a			0.0259
b			2.836
r			0.96
n			253

ELEFAN Parameters

File Name	Eaffrps9901.lfq
Rn	
SS/SL	

Selection Parameters	
L 25	27.1
L 50	31.5
L 75	36.0
Lc/ L∞	0.35
tc	0.476

Maturity Parameters	
L_m	47
Peak breeding	Sep-Oct
L_m / L_∞	0.53
Generation time (t_g=t_{opt})	1.26 yr

Population Parameters

Z	4.95
CI of Z	4.47-5.42
M	1.26
F	3.69
E (F/Z)	0.75
L_{opt}	60.6
F_{opt}	3.78

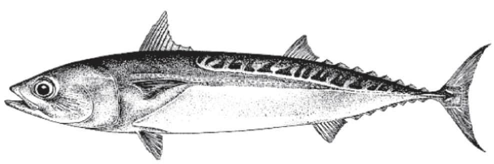
Ecopath Parameters

P/B	4.95
Q/B	14.11
Ar	5.94
Biomass	2668 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.14

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Auxis rochei* Common Name : Bullet Tuna (Kedar) Family : Scombridae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **GN, PS**
	Fleet : DGN, PS
	Habitat Area : 27,000 km^2
	Ecological Grouping : 4. Large pelagics
	Data Source : **Other**
	Annual Ave Catch : 286 t



Growth Parameters

L_{max}/t_{max}	38
L_r	
L'	27
L_{mean}	31
L_∞	40
K	1.1 yr^{-1}
φ'	
W_∞	1129 g
t_0	-0.0106

LW Parameters

	Male	Female	Combined
a			0.00464
b			3.362
r			0.99
n			

ELEFAN Parameters

File Name	Argnps990001.lfq
R_n	0.349
SS/SL	2 / 25

Selection Parameters	
L-25	29
L-50	33
L-75	37
L_c/L_∞	0.83
t_c	1.57

Maturity Parameters	
L_m	22.9
Peak breeding	
L_m/L_∞	0.57
Generation time (t_g=t_{opt})	

Population Parameters

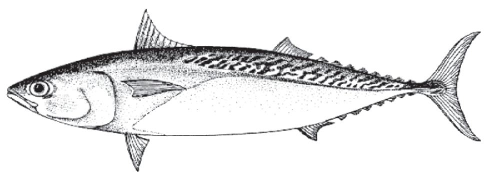
Z	4.72
CI of Z	2.53-6.92
M	1.80
F	2.93
E (F/Z)	0.62
L_{opt}	
F_{opt}	

Ecopath Parameters

P/B	4.72
Q/B	17.7
Ar	4.94
Biomass	461 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.14

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Auxis thazard* Common Name : Frigate Tuna (Kedar) Family : Scombridae		Centre : Mangalore
		Period : 1999 - 2000
		Gears Exploiting : GN, PS
		Fleet : DGN, PS
		Habitat Area : 27,000 km^2
		Ecological Grouping : 5. Tunas
		Data Source : Other
		Annual Ave Catch : 487 t

Growth Parameters		
L_{max}/t_{max}	52
L_r	22.3
L'	35
L_{mean}	39.8
L_∞	54
K	0.87 yr^{-1}
ϕ'	3.4042
W_∞	2932 g
t_0	-0.0169

LW Parameters	Male	Female	Combined
a			0.0075
b			3.228
r			0.96
n			261

ELEFAN Parameters	
File Name	Atgnps99/00/01
R_n	
SS/SL	

Selection Parameters	
L-25	31
L-50	33
L-75	35
L_c/L_∞	0.61
t_c	1.07

Maturity Parameters	
L_m	30
Peak breeding	Aug-Oct
L_m/L_∞	0.56
Generation time ($t_g = t_{opt}$)	1.184 yr

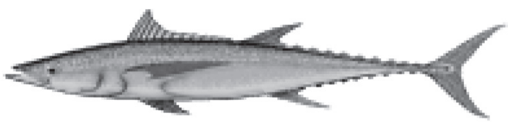
Population Parameters	
Z	3.74
CI of Z	2.99-4.5
M	1.42
F	2.32
E (F/Z)	0.62
F_{opt}	2.31
L_{opt}	34.97

Ecopath Parameters	
P/B	3.74
Q/B	15.05
Ar	5.11
Biomass	786 t
EE	0.58
Feeding type	Carnivore
Trophic level	4.14

Remarks: Data from literature (Muthiah *et.al*)
All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Thunnus tonggol* Common Name : Long tail tuna (kedar) Family : Scombridae	Centre : Mangalore
	Period : 1999 - 2001
	Gears Exploiting : **GN**, **PS**
	Fleet : DGN, PS
	Habitat Area : 27000 km^2
	Ecological Grouping 5. Tunas
	Data Source : **Other**
	Annual Ave Catch : 177 t



Growth Parameters

L_{max}/t_{max}	70.0
L_r	32.0
L'	39.0
L_{mean}	47.5
L_∞	92.1
K	1.2 yr^{-1}
ϕ’	4.0115
W_∞	8195 g
t_0	-0.0066

LW Parameters

	Male	Female	Combined
a			0.0545
b			2.636
r			0.98
n			260

ELEFAN Parameters

File Name	Ttgnps00, 99 .lfq (2files)
R_n	
SS/SL	

Selection Parameters	
L-25	32.4
L-50	35.0
L-75	37.0
L_c/L_∞	0.38
t_c	0.39 yr

Maturity Parameters	
L_m	48.5
Peak breeding	
L_m/L_∞	0.53
Generation time (t_g=t_{opt})	1.0 yr

Population Parameters

Z	6.7
CI of Z	4.86-8.53
M	1.51
F	5.19
E (F/Z)	0.78
L_{opt}	65.0
F_{opt}	5.35

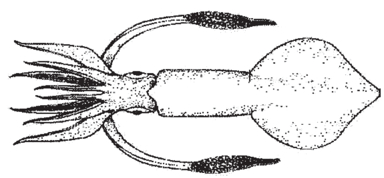
Ecopath Parameters

P/B	6.7
Q/B	18.29
Ar	7.23
Biomass	227 t
EE	0.60
Feeding type	Carnivore
Trophic level	4.14

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Loligo duvaucelii*	Centre : Mangalore + Malpe
Common Name : Squid (Bondase)	Period : 2000 - 2001
Family : Loliginidae	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 6. Cephalopods
	Data Source : **Other**
	Annual Ave Catch : 4434 t



Growth Parameters	
L_{max}/t_{max}	34.0
L_r	3.0
L'	8.9
L_{mean}	12.5
L_∞	37.4
K	1.4 yr^{-1}
ϕ'	3.2919
W_∞	652 g
t_0	-0.0053

LW Parameters	Male	Female	Combined
a			0.0025
b			2.105
r			0.97
n			372

ELEFAN Parameters	
File Name	Ldmfsm.lfq
R_n	
SS/SL	

Selection Parameters	
L-25	5.9
L-50	6.8
L-75	7.7
L_c / L_∞	0.18
t_c	0.14 yr

Maturity Parameters	
L_m	21.6
Peak breeding	Sep-Dec
L_m / L_∞	0.58
Generation time (t_g=t_{opt})	0.77 yr

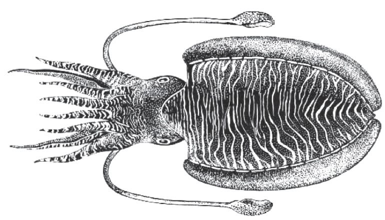
Population Parameters	
Z	5.98
CI of Z	5.32-6.64
M	2.14
F	3.84
E (F/Z)	0.64
L_{opt}	24.8
F_{opt}	3.8

Ecopath Parameters	
P/B	5.98
Q/B	36.5
Ar	
Biomass	6927 t
EE	0.84
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sepia pharaonis* Common Name : Cuttlefish (kappe bondase) Family : Sepiidae	Centre : Mangalore + Malpe
	Period : 2000 - 2001
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 6. Cephalopods
	Data Source : **Other**
	Annual Ave Catch : 676 t



Growth Parameters

L_{max}/t_{max}	31.0
L_r	
L'	17.0
L_{mean}	21.4
L_∞	33.1
K	1 yr^{-1}
ϕ'	3.0397
W_∞	456 g
t_0	-0.0142

LW Parameters

	Male	Female	Combined
a			0.00625
b			3.2
r			0.989
n			

ELEFAN Parameters

File Name	Sephar.lfq
Rn	0.16
SS/SL	5 / 16.5

Selection Parameters	
L-25	11.4
L-50	12.9
L-75	15.7
L_c / L_∞	0.39
t_c	0.48 yr

Maturity Parameters	
L_m	19.4
Peak breeding	Oct-Apr
L_m / L_∞	0.58
Generation time (t_g=t_{opt})	0.97 yr

Population Parameters

Z	2.52
CI of Z	2.27-2.77
M	1.78
F	0.74
E (F/Z)	0.29
L_{opt}	20.8
F_{opt}	0.73

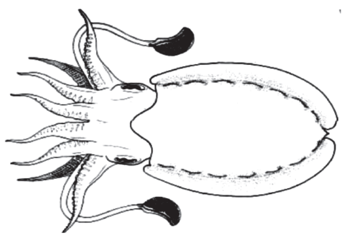
Ecopath Parameters

P/B	2.52
Q/B	36.5
Ar	
Biomass	2332.t
EE	0.84
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sepia elliptica* Common Name : Cuttlefish (kappe bondase) Family : Sepiidae	Centre : Mangalore + Malpe
	Period : 2000 - 2001
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 6. Cephalopods
	Data Source : **Other**
	Annual Ave Catch : 75 t



Growth Parameters		LW Parameters	Male	Female	Combined
L_{max}/t_{max}	13.0				
L_r		a			0.00625
L'	8.0	b			3.2
L_{mean}	9.7	r			0.959
L_∞	13.8	n			
K	1.4 yr^{-1}	**ELEFAN Parameters**			
ϕ'	2.4259	File Name	Sepellpt.lfq		
W_∞	28 g	R_n	0.784		
t_0	-0.0069	SS/SL	4/10		

Selection Parameters	
L-25	
L-50	
L-75	
L_c/L_∞	
t_c	

Maturity Parameters	
L_m	8.8
Peak breeding	
L_m/L_∞	0.64
Generation time (t_g=t_{opt})	0.64 yr

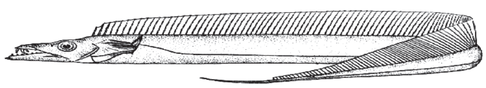
Population Parameters	
Z	5.41
CI of Z	2.48-8.35
M	2.83
F	2.58
E (F/Z)	0.48
L_{opt}	8.24
F_{opt}	2.61

Ecopath Parameters	
P/B	5.41
Q/B	
Ar	
Biomass	156 t
EE	0.84
Feeding type	Carnivore
Trophic level	4.18

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Trichiurus lepturus* Common Name : Ribbon fish (Pambole) Family : Trichiuridae	Centre : Mangalore
	Period : 1999 - 2000
	Gears Exploiting : **TR**, **PS**
	Fleet : MDF, SDF, PF
	Habitat Area : 27000 km^2
	Ecological Grouping : 7 Large Benthopelagics
	Data Source : **Other**
	Annual Ave Catch : 6380 t



Growth Parameters

L_{max}/t_{max}	120.0
L_r	36.0
L'	51.0
L_{mean}	64.0
L_∞	125.0
K	0.88 yr^{-1}
ϕ'	4.1283
W_∞	1286 g
t_0	-0.0131

LW Parameters

	Male	Female	Combined
a	0.0013	0.0006	
b	2.819	3.029	
r	0.91	0.95	
n	200	200	

ELEFAN Parameters

File Name	TL99-01m. lfq
R_n	0.126
SS/SL	58/ 26

Selection Parameters	
L-25	41.0
L-50	47.0
L-75	51.0
L_c/L_∞	0.38
t_c	0.52 yr

Maturity Parameters	
L_m	63.8
Peak breeding	
L_m/L_∞	0.51
Generation time (t_g=t_{opt})	1.36 yr

Population Parameters

Z	4.68
CI of Z	4.35-5.91
M	1.13
F	3.55
E (F/Z)	0.76
L_{opt}	87.5
F_{opt}	3.6

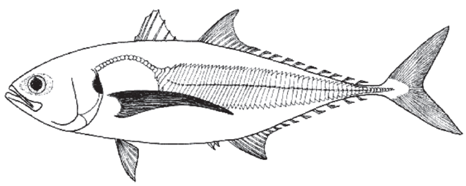
Ecopath Parameters

P/B	4.68
Q/B	6.72
Ar	0.01
Biomass	8395 t
EE	0.98
Feeding type	Carnivore
Trophic level	4.15

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name	:	*Megalaspis cordyla*
Common Name	:	Torpedo Scad (Kodanthe)
Family	:	Carangidae



Centre : Mangalore
Period : 1999-2000
Gears Exploiting : **TR**, **PS**
Fleet : MDF, PS
Habitat Area : 27000 km^2
Ecological Grouping : 7. Large Bentho Pelagics
Data Source : **Project**
Annual Ave Catch : 2377 t

Growth Parameters

L_{max}/t_{max}	50.1
L_r	15.5
L'	23.0
L_{mean}	28.0
L_∞	53.4
K	0.99 yr^{-1}
ϕ'	3.4507
W_∞	1048 g
t_0	-0.0127

LW Parameters

	Male	Female	Combined
a	0.0323	0.0199	
b	2.582	2.748	
r	0.85	0.98	
n	200	200	

ELEFAN Parameters

File Name	Mcorsm.lfq
R_n	0.147
SS/SL	5/ 23.5

Selection Parameters	
L-25	20.0
L-50	21.6
L-75	22.7
L_c/L_∞	0.4
t_c	0.51 yr

Maturity Parameters	
L_m	29.7
Peak breeding	
L_m/L_∞	0.56
Generation time (t_g=t_{opt})	1.07 yr

Population Parameters

Z	6.31
CI of Z	5.88-6.74
M	1.55
F	4.76
E (F/Z)	0.75
L_{opt}	35.1
F_{opt}	4.65

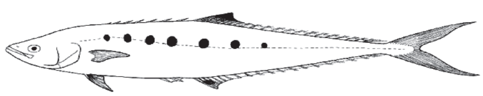
Ecopath Parameters

P/B	6.31
Q/B	18.74
Ar	5.16
Biomass	3169 t
EE	0.97
Feeding type	Carnivore
Trophic level	4.15

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Scomberoides tol* Common Name : Needle scaled queen fish (Palai menu) Family : Carangidae	Centre : Mangalore + Malpe
	Period : 2000-01
	Gears Exploiting : **TR**, **PS**
	Fleet : MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 7 Large Benthopelagics
	Data Source : **Project**
	Annual Ave Catch : 200 t



Growth Parameters

L_{max}/t_{max}	45.0
L_r	14.0
L'	37.0
L_{mean}	39.3
L_∞	46.0
K	0.98 yr^{-1}
φ'	3.3167
W_∞	641 g
t_0	-0.0136

LW Parameters

	Male	Female	Combined
a	0.0069	0.0068	0.0174
b	2.937	2.955	2.746
r	0.99	0.99	0.947
n	59	66	125

ELEFAN Parameters

File Name	Stol.lfq
R_n	0.229
SS/SL	2/37

Selection Parameters	
L-25	35.9
L-50	36.7
L-75	37.6
L_c/L_∞	0.8
t_c	1.62 yr

Maturity Parameters	
L_m	26.0
Peak breeding	
L_m/L_∞	0.56
Generation time (t_g=t_{opt})	1.1 yr

Population Parameters

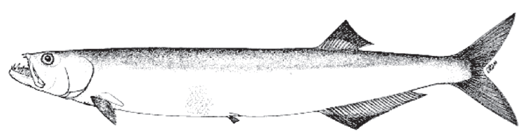
Z	4.84
CI of Z	3.09-6.58
M	1.59
F	3.25
E (F/Z)	0.67
L_{opt}	30.0
F_{opt}	3.2

Ecopath Parameters

P/B	4.84
Q/B	18.76
Ar	4.64
Biomass	299 t
EE	0.97
Feeding type	Carnivore
Trophic level	4.15

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Chirocentrus dorab* Common Name : Wolf Herring (Karli) Family : Chirocentridae	Centre : Mangalore
	Period : 1999-2001
	Gears Exploiting : TR, GN
	Fleet : MDF, DGN
	Habitat Area : 27,000 km^2
	Ecological Grouping : 7 Large Bentho-pelagics
	Data Source : Project
	Annual Ave Catch : 255 t

Growth Parameters

L_{max}/t_{max}	62
L_r	26.4
L'	40
L_{mean}	45.3
L_∞	67.4
K	0.57 yr^{-1}
ϕ'	3.4132
W_∞	986 g
t_0	-0.0326

LW Parameters

	Male	Female	Combined
a	0.0066	0.0034	
b	2.801	2.801	
r	0.97	0.97	
n	109	76	

ELEFAN Parameters

File Name	Cdarab98/99. lfq
Rn	0.386
SS/SL	4/ 350

Selection Parameters	
L-25	31.1
L-50	35.8
L-75	40.4
L_c / L_∞	0.53
t_c	1.30

Maturity Parameters	
L_m	36.6
Peak breeding	
L_m / L_∞	0.54
Generation time (tg= topt)	1.71 yr

Population Parameters

Z	2.7
CI of Z	2.23-3.16
M	1.01
F	1.69
E (F/Z)	0.63
L_{opt}	42
F_{opt}	1.72

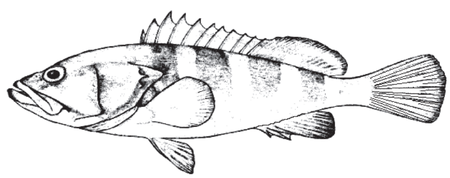
Ecopath Parameters

P/B	2.7
Q/B	13.05
Ar	3.2
Biomass	405 t
EE	0.97
Feeding type	Carnivore
Trophic level	4.15

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Epinephelus diacanthus* Common Name : Rock Cod (Murimeenu) Family : Serranidae	Centre : Mangalore
	Period : 1999-2001
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 8 Large Benthic Carnivore
	Data Source : **Project**
	Annual Ave Catch : 1781 t



Growth Parameters

L_{max}/t_{max}	55.4
L_r	14.7
L’	18
L_{mean}	23.7
L_∞	57.2
K	1.1 yr^{-1}
ϕ’	3.5562
W_∞	1542 g
t_0	-0.0096

LW Parameters

	Male	Female	Combined
a			0.0584
b			2.516
r			0.87
n			200

ELEFAN Parameters

File Name	Epinepsm.lfq
Rn	0.165
SS/SL	5/ 15

Selection Parameters	
L-25	11.7
L-50	12.6
L-75	13.5
L_c/L_∞	0.235
t_c	0.216

Maturity Parameters	
L_m	31.6
Peak breeding	
L_m/L_∞	0.55
Generation time (t_g=t_{opt})	1.0 yr

Population Parameters

Z	4.16
CI of Z	3.78-4.54
M	1.63
F	2.53
E (F/Z)	0.61
L_{opt}	38.3
F_{opt}	2.54

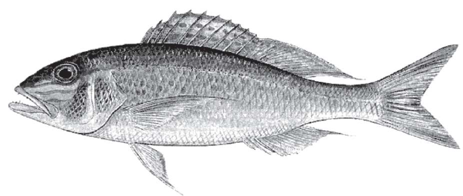
Ecopath Parameters

P/B	4.16
Q/B	8.16
Ar	1.22
Biomass	2919 t
EE	0.98
Feeding type	Carnivore
Trophic level	4.14

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Pristipomoides filamentosus* Common Name : Sharptooth jobfish (Chembally) Family : Lutjanidae	Centre : Mangalore
	Period : 1999-2000
	Gears Exploiting : TR, H&L
	Fleet : MDF, H&L
	Habitat Area : 27000 km^2
	Ecological Grouping : 8 Large Benthic Carnivores
	Data Source : Project
	Annual Ave Catch : 805 t



Growth Parameters

L_{max}/t_{max}	62.5
L_r	15.2
L'	25.0
L_{mean}	37.0
L_∞	70.0
K	0.53 yr^{-1}
ϕ’	3.4145
W_∞	7042 g
t_0	-0.0355

LW Parameters

	Male	Female	Combined
a	0.0136	0.0134	
b	2.898	2.910	
r	0.99	0.99	
n	42	25	

ELEFAN Parameters

File Name	Prilfsm.lfq
R_n	0.35
SS/SL	6/ 37.5

Selection Parameters	
L-25	
L-50	
L-75	
L_c / L_∞	
t_c	

Maturity Parameters	
L_m	37.9
Peak breeding	
L_m / L_∞	0.54
Generation time (t_g=t_{opt})	1.82 yr

Population Parameters

Z	1.74
CI of Z	1.33-2.14
M	0.95
F	0.79
E (F/Z)	0.45
L_{opt}	43.8
F_{opt}	0.8

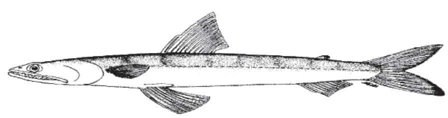
Ecopath Parameters

P/B	1.74
Q/B	8.14
Ar	2.83
Biomass	1788 t
EE	0.98
Feeding type	Carnivore
Trophic level	4.14

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Saurida tumbil* Common Name : Greater lizard fish (Aranemenu) Family : Synodontidae	Centre : Mangalore
	Period : 1995 - 96
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 8 Large Benthic carnivore
	Data Source : **Other**
	Annual Ave Catch : 2120 t



Growth Parameters

L_{max}/t_{max}	48.3
L_r	10.1
L'	
L_{mean}	
L_∞	57.5
K	0.57 yr^{-1}
φ’	3.275
W_∞	1609 g
t_0	0.0216

LW Parameters

	Male	Female	Combined
a			0.00000343
b			3.142
r			0.99
n			2819

ELEFAN Parameters

File Name	Muthiah
R_n	0.2
SS/SL	

Selection Parameters	
L-25	
L-50	
L-75	
L_c/L_∞	
t_c	

Maturity Parameters	
L_m	31.8
Peak breeding	Oct-Jan
L_m/L_∞	0.55
Generation time ($t_g=t_{opt}$)	1.62 yr

Population Parameters

Z	3.70
CI of Z	
M	1.15
F	2.55
E (F/Z)	0.69
L_{opt}	34.4
F_{opt}	1.13

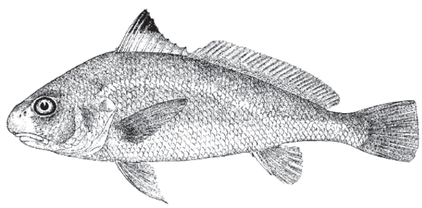
Ecopath Parameters

P/B	3.7
Q/B	8.24
Ar	1.32
Biomass	2141 t
EE	0.95
Feeding type	Carnivore
Trophic level	4.14

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Johnieops sina*	Centre : Mangalore
Common Name : Sin Croaker (Kalluru)	Period : 1999-2000
Family : Sciaenidae	Gears Exploiting : **TR**, **PS**, **AS**
	Fleet : MDF, SDF, PS, AS
	Habitat Area : 27000 km^2
	Ecological Grouping : 9. Medium Benthic carnivores
	Data Source : **Project**
	Annual Ave Catch : 917 t



Growth Parameters

L_{max}/t_{max}	19.3
L_r	10.0
L'	13.0
L_{mean}	14.3
L_∞	19.9
K	0.98 yr^{-1}
φ'	2.5889
W_∞	95 g
t_0	-0.0171

LW Parameters

	Male	Female	Combined
a	0.0520	0.0174	
b	2.420	2.869	
r	0.85	0.94	
n	150	229	

ELEFAN Parameters

File Name	Jsina2.lfq
R_n	0.274
SS/SL	7/ 13.5

Selection Parameters

L-25	12.1
L-50	12.8
L-75	13.6
L_c/L_∞	0.63
t_c	1.04 yr

Maturity Parameters

L_m	12.2
Peak breeding	
L_m/L_∞	0.62
Generation time ($t_g=t_{opt}$)	0.9 yr

Population Parameters

Z	8.36
CI of Z	5.61-11.1
M	2.02
F	6.33
E (F/Z)	0.76
L_{opt}	11.8
F_{opt}	6.39

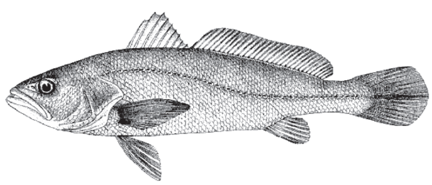
Ecopath Parameters

P/B	8.36
Q/B	19.1
Ar	2.69
Biomass	1206 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Otolithus ruber* Common Name : Tiger tooth croaker (Koddai) Family : Sciaenidae	Centre : Mangalore
	Period : 1999-2000
	Gears Exploiting : **TR, PS**
	Fleet : SDF, MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 9 Medium Benthic carnivore
	Data Source : **Project**
	Annual Ave Catch : 1080 t



Growth Parameters

Parameter	Value
L_{max}/t_{max}	29.5
L_r	11.2
L'	15.5
L_{mean}	17.2
L_∞	33.7
K	0.83 yr^{-1}
ϕ'	2.9743
W_∞	370 g
t_0	-0.0212

LW Parameters

	Male	Female	Combined
a	0.0135	0.0113	
b	2.897	2.961	
r	0.98	0.94	
n	108	177	

ELEFAN Parameters

File Name	Oruber9900.lfq
R_n	0.15
SS/SL	2/ 21.5

Selection Parameters	
L-25	11.1
L-50	13.7
L-75	14.3
L_c/L_∞	0.41
t_c	0.58 yr

Maturity Parameters	
L_m	19.7
Peak breeding	Oct-Jan
L_m/L_∞	0.58
Generation time (t_g=t_{opt})	1.12 yr

Population Parameters

Z	5.42
CI of Z	4.18-6.05
M	1.57
F	3.85
E (F/Z)	0.71
L_{opt}	20.7
F_{opt}	3.80

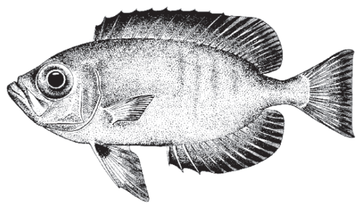
Ecopath Parameters

P/B	5.42
Q/B	10.69
Ar	1.11
Biomass	1521 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Priacanthus hamrur* Common Name : Moontail Bulls Eye (Discomeenu) Family : Priacanthidae	Centre : Mangalore
	Period : 1999-2000
	Gears Exploiting : TR
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 9 Medium Benthic Carnivores
	Data Source : Project
	Annual Ave Catch : 959 t



Growth Parameters

L_{max}/t_{max}	28.2
L_r	15.8
L'	21.0
L_{mean}	23.2
L_∞	32.0
K	1.2 yr^{-1}
φ'	3.0895
W_∞	387 g
t_0	-0.0089

LW Parameters

	Male	Female	Combined
a	0.0169	0.0234	
b	2.905	2.787	
r	0.97	0.9	
n	38	165	

ELEFAN Parameters

File Name	Prilfsm.lfq
R_n	0.418
SS/SL	1/ 17.5

Selection Parameters

L-25	16.6
L-50	19.5
L-75	20.8
L_c/L_∞	0.61
t_c	0.8 yr

Maturity Parameters

L_m	18.8
Peak breeding	
L_m/L_∞	0.59
Generation time ($t_g=t_{opt}$)	0.84 yr

Population Parameters

Z	5.2
CI of Z	4.91-5.49
M	2.02
F	3.18
E (F/Z)	0.61
L_{opt}	20.5
F_{opt}	3.2

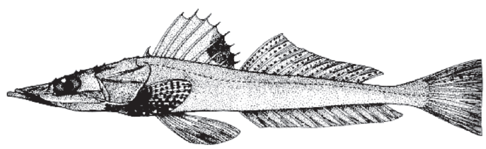
Ecopath Parameters

P/B	5.2
Q/B	14.93
Ar	2.91
Biomass	1572 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name	: *Grammoplitus suppositus*
Common Name	: Flat head (Balchet)
Family	: Platycephalidae



Centre : Mangalore - Malpe
Period : 1999-2000
Gears Exploiting : **TR**
Fleet : MDF
Habitat Area : 27000 km^2
Ecological Grouping : 9 Medium Benthic carnivore
Data Source : **Project**
Annual Ave Catch : 2485 t

Growth Parameters

L_{max}/t_{max}	30.0
L_r	14.3
L'	22.0
L_{mean}	23.6
L_∞	31.5
K	0.96 yr^{-1}
ϕ'	2.98
W_∞	206 g
t_0	-0.0158

LW Parameters

	Male	Female	Combined
a	0.0126	0.0117	0.01215
b	2.798	2.846	2.822
r			0.88
n			393

ELEFAN Parameters

File Name	Gsuppo.lfq
R_n	0.292
SS/SL	3/165

Selection Parameters	
L-25	19.4
L-50	20.9
L-75	22.0
L_c / L_∞	0.66
t_c	1.13 yr

Maturity Parameters	
L_m	18.5 cm
Peak breeding	
L_m / L_∞	0.59
Generation time (t_g=t_{opt})	1.0 yr

Population Parameters

Z	4.62
CI of Z	4.0 –5.25
M	1.76
F	2.87
E (F/Z)	0.62
L_{opt}	19.5
F_{opt}	2.871
Recruit period	Dec-Apr

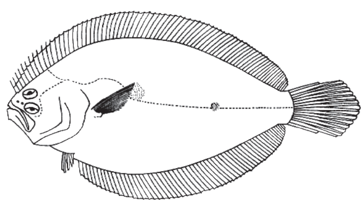
Ecopath Parameters

P/B	4.62
Q/B	19.13
Ar	3.53
Biomass	4008 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Pseudorhombus arsius* Common Name : Large toothed flounder (Thibile nangu) Family : Bothidae	Centre : Mangalore
	Period : 1999-2000
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 9 Medium Benthic carnivores
	Data Source : **Project**
	Annual Ave Catch : 561 t



Growth Parameters

Parameter	Value
L_{max}/t_{max}	31.5
L_r	13.7
L'	22.0
L_{mean}	25.2
L_∞	35.0
K	1.3 yr^{-1}
ϕ’	3.2021
W_∞	443 g
t_0	-0.0068

LW Parameters

	Male	Female	Combined
a	0.0039	0.0028	
b	3.256	3.378	
r	0.98	0.99	
n	1.47	160	

ELEFAN Parameters

File Name	Parsiusm.lfq
R_n	0.265
SS/SL	4/ 26.0

Selection Parameters

L-25	16.5
L-50	19.3
L-75	20.6
$L_c/L_¥$	0.55
t_c	0.61 yr

Maturity Parameters

L_m	20.3
Peak breeding	
L_m/L_∞	0.58
Generation time (t_g=t_{opt})	0.81 yr

Population Parameters

Z	3.63
CI of Z	3.33-3.93
M	2.08
F	1.55
E (F/Z)	0.42
L_{opt}	22.8
F_{opt}	1.51

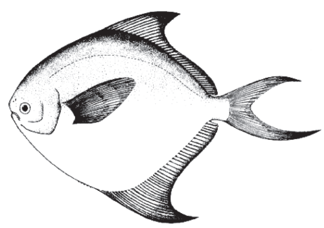
Ecopath Parameters

P/B	3.63
Q/B	10.36
Ar	1.14
Biomass	1335 t
EE	0.98
Feeding type	Carnivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Pampus argenteus* Common Name : Silver pomfret (Boldhu manji) Family : Stromateidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **TR**, **PS**
	Fleet : MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 9 Medium Benthic carnivores
	Data Source : **Project**
	Annual Ave Catch : 441 t



Growth Parameters

L_{max}/t_{max}	28.7
L_r	9.0
L'	16.5
L_{mean}	19.9
L_∞	33.0
K	1.4 yr^{-1}
ϕ'	3.1832
W_∞	686 g
t_0	-0.0055

LW Parameters

	Male	Female	Combined
a	0.1199	0.3865	
b	2.485	2.036	
r	0.96	0.98	
n	90	54	

ELEFAN Parameters

File Name	Pargensm.lfq
R_n	0.265
SS/SL	1/ 21.5

Selection Parameters

L-25	8.6
L-50	10.1
L-75	13.8
L_c/L_∞	0.31
t_c	0.26 yr

Maturity Parameters

L_m	19.3
Peak breeding	
L_m/L_∞	0.58
Generation time (t_g=t_{opt})	0.75 yr

Population Parameters

Z	4.21
CI of Z	3.1-5.31
M	2.22
F	1.99
E (F/Z)	0.47
L_{opt}	21.6
F_{opt}	2.0

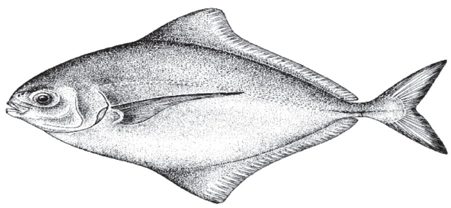
Ecopath Parameters

P/B	4.21
Q/B	31.20
Ar	2.58
Biomass	939 t
EE	0.95
Feeding type	Detritivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Formio niger*	Centre : Mangalore
Common Name : Black Pomfret (Kappu manji)	Period : 2000-01
Family : Carangidae	Gears Exploiting : **TR**, **PS**
	Fleet : MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 9 Medium Benthic Carnivores
	Data Source : **Project**
	Annual Ave Catch : 1049 t



Growth Parameters

L_{max}/t_{max}	57.5
L_r	17.2
L’	13
Lmean	20.2
L_∞	62.7
K	0.72 yr^{-1}
ϕ’	3.4519
W_∞	3024 g
t_0	-0.0232

LW Parameters

	Male	Female	Combined
a	0.0527	0.0685	
b	2.655	2.573	
r	0.98	0.96	
n	23	12	

ELEFAN Parameters

File Name	Fnigersm.lfq
R_n	0.156
SS/SL	2/ 22

Selection Parameters

L 25	9.7
L 50	10.0
L 75	10.8
Lc/ L∞	0.16
tc	0.22 yr

Maturity Parameters

L_m	19.1
Peak breeding	Oct-Dec
L_m/L_∞	0.30
Generation time (t_g=t_{opt})	0.54 yr

Population Parameters

Z	2.70
CI of Z	2.41-2.98
M	1.20
F	1.50
E (F/Z)	0.55
L_{opt}	21
F_{opt}	1.47

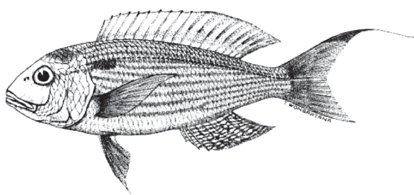
Ecopath Parameters

P/B	2.7
Q/B	9.52
Ar	2.75
Biomass	1907 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.19

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name	: *Nemipterus japonicus*
Common Name	: Japanese Threadfin bream (Madhumal meenu)
Family	: Nemipteridae



Centre : Mangalore
Period : 1999-2001
Gears Exploiting : **TR**
Fleet : MDF
Habitat Area : 27000 km^2
Ecological Grouping : 10 Small Benthic Carnivore
Data Source : **Other**
Annual Ave Catch : 6572 t

Growth Parameters

L_{max}/t_{max}	31.5
L_r	9.5
L'	16.0
L_{mean}	19.6
L_∞	32.0
K	1.4 yr^{-1}
ϕ'	3.1564
W_∞	395 g
t_0	-0.0055

LW Parameters

	Male	Female	Combined
a			0.0386
b			2.664
r			0.99
n			408

ELEFAN Parameters

File Name	Njap99,200,2001.lfq (3files)
R_n	
SS/SL	

Selection Parameters	
L-25	11.0
L-50	12.8
L-75	14.8
L_c/L_∞	0.4
t_c	0.36 yr

Maturity Parameters	
L_m	18.8
Peak breeding	Oct-Dec, Apr-May
L_m/L_∞	0.59
Generation time (t_g=t_{opt})	0.75 yr

Population Parameters

Z	5.04
CI of Z	4.89-5.19
M	2.24
F	2.80
E (F/Z)	0.56
L_{opt}	20.9 cm
F_{opt}	2.85

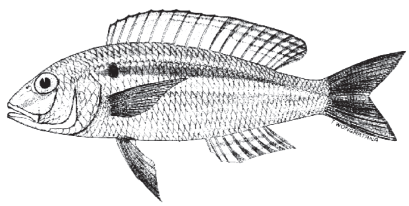
Ecopath Parameters

P/B	5.04
Q/B	12.79
Ar	2.12
Biomass	11735 t
EE	0.95
Feeding type	Carnivore
Trophic level	2.68

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Nemipterus mesoprion*	Centre : Mangalore
Common Name : Red filament Threadfin bream (Madhumal meenu)	Period : 1999-2001
Family : Nemipteridae	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 10 Small Benthic carnivore
	Data Source : **Other**
	Annual Ave Catch : 11771 t



Growth Parameters

Lmax/t max	25.5
Lr	12.9
L’	17.0
Lmean	19.3
L_∞	29.0
K	1.1 yr^{-1}
ϕ’	2.9662
W_∞	313 g
t_0	-0.0116

LW Parameters

	Male	Female	Combined
a	0.0347	0.0182	0.02645
b	2.673	2.889	2.7855
r	0.96	0.96	
n	210	200	

ELEFAN Parameters

File Name	Nmeso99,200,2001.lfq (3files)
R_n	
SS/SL	

Selection Parameters	
L 25	8.5
L 50	9.8
L 75	11.0
Lc/ L∞	0.38
t_c	0.36 yr

Maturity Parameters	
Lm50	17.2
Peak breeding	
Lm/ L∞	0.59
Generation time (tg=topt)	0.88 yr

Population Parameters

Z	4.48
CI of Z	4.32-4.64
M	1.97
F	2.52
E (F/Z)	0.56
L_{opt}	18.2
F_{opt}	2.5

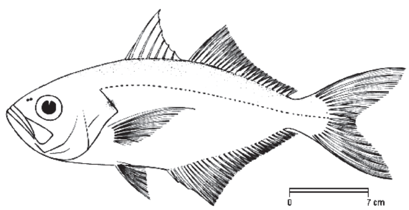
Ecopath Parameters

P/B	4.48
Q/B	11.89
Ar	1.49
Biomass	21019 t
EE	0.95
Feeding type	Carnivore
Trophic level	2.68

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Lactarius lactarius*	Centre : Mangalore
Common Name : White fish (Ademeenu)	Period : 1999-2001
Family : Lactaridae	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 10 Small Benthic Carnivores
	Data Source : **Other**
	Annual Ave Catch : 1191 t



Growth Parameters

L_{max}/t_{max}	26.5
L_r	8.5
L'	13.0
L_{mean}	15.0
L_∞	28.6
K	0.82
φ’	2.8255
W_∞	253 g
t_0	-0.0228

LW Parameters

	Male	Female	Combined
a	0.0175	0.0150	0.01625
b	2.853	2.905	2.879
r	0.93	0.96	
n	250	274	

ELEFAN Parameters

File Name	Zach
R_n	
SS/SL	

Selection Parameters	
L-25	
L-50	
L-75	
L_c / L_∞	
t_c	

Maturity Parameters	
L_m	17.0
Peak breeding	Feb-Apr
L_m / L_∞	0.59
Generation time (t_g=t_{opt})	1.31 yr

Population Parameters

Z	5.78
CI of Z	
M	1.56
F	4.22
E (F/Z)	0.73
L_{opt}	17.46
F_{opt}	4.22

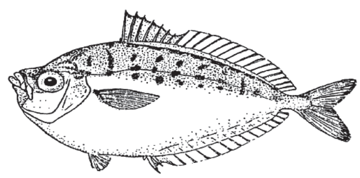
Ecopath Parameters

P/B	5.78
Q/B	15.29
Ar	2.58
Biomass	1631 t
EE	0.95
Feeding type	Carnivore
Trophic level	2.68

Remarks: Data from Zacharia (unpubl)
All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Secutor insidiator*
Common Name : Pug nose pony fish (Kurichi)
Family : Leiognathidae



Centre : Mangalore	
Period : 2000-01	
Gears Exploiting : **TR**	
Fleet : SDF/MDF, PS	
Habitat Area : 27000 km^2	
Ecological Grouping : 10 Small Benthic carnivores	
Data Source : **Project**	
Annual Ave Catch : 1373 t	

Growth Parameters

L_{max}/t_{max}	11.3
L_r	6.6
L'	9.0
L_{mean}	9.7
L_∞	11.9
K	1.4 yr^{-1}
ϕ'	2.2972
W_∞	23 g
t_0	-0.0072

LW Parameters

	Male	Female	Combined
a	0.0228	0.0176	0.0202
b	2.782	2.907	2.8445
r	0.94	0.94	
n	101	101	

ELEFAN Parameters

File Name	Sinsd00m,01m. lfq (2fil)
R_n	0.292
SS/SL	2/ 9.75

Selection Parameters	
L-25	8.2
L-50	8.7
L-75	9.1
L_c / L_∞	0.73
t_c	0.93 yr

Maturity Parameters	
L_m	7.7
Peak breeding	Jul-Nov, Mar-Apr
L_m / L_∞	0.65
Generation time (t_g=t_{opt})	0.63 yr

Population Parameters

Z	4.77
CI of Z	4.06-5.48
M	2.95
F	1.82
E (F/Z)	0.38
L_{opt}	7.00
F_{opt}	1.81

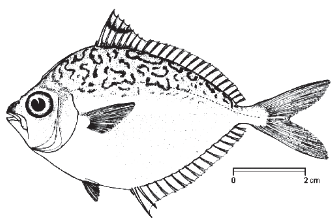
Ecopath Parameters

P/B	4.77
Q/B	48.95
Ar	1.32
Biomass	3613 t
EE	0.95
Feeding type	Detritivore
Trophic level	2.68

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Leiognathus bindus* Common Name : Orange fin pony fish (Kurichi) Family : Leiognathidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **TR**, **PS**
	Fleet : SDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 10 Small Benthic Carnivores
	Data Source : **Project**
	Annual Ave Catch : 608 t



Growth Parameters

L_{max}/t_{max}	12.3
L_r	7.3
L'	9.5
L_{mean}	10.1
L_∞	13.3
K	0.96 yr^{-1}
ϕ'	2.2300
W_∞	31.4 g
t_0	-0.0201

LW Parameters

	Male	Female	Combined
a	0.0437	0.1263	0.085
b	2.521	2.054	2.2875
r	0.85	0.67	
n	149	141	

ELEFAN Parameters

File Name	Lbind00m, 01.lfq (2files)
R_n	0.435
SS/SL	4/ 10.25

Selection Parameters	
L-25	8.5
L-50	9.0
L-75	9.5
L_c/L_∞	0.68
t_c	1.2 yr

Maturity Parameters	
L_m	8.6
Peak breeding	
L_m/L_∞	0.64
Generation time (t_g=t_{opt})	0.84 yr

Population Parameters

Z	6.27
CI of Z	5.35-7.19
M	2.24
F	4.03
E (F/Z)	0.64
L_{opt}	7.46
F_{opt}	3.98

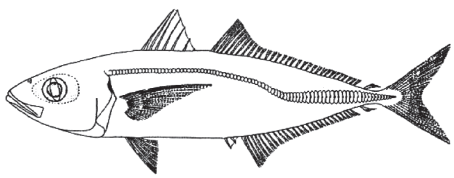
Ecopath Parameters

P/B	6.27
Q/B	53.7
Ar	2.13
Biomass	950 t
EE	0.95
Feeding type	Detritvore
Trophic level	2.68

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Decapterus ruselli* Common Name : Indian Scad (Tidimba) Family : Carangidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : TR, PS
	Fleet : SDF/MDF, PS
	Habitat Area : 27,000 km^2
	Ecological Grouping : 11 Small Bentho-pelagics
	Data Source : Other
	Annual Ave Catch : 2307 t



Growth Parameters

L_{max}/t_{max}	22
L_r	8.3
L'	
L_{mean}	
L_∞	23.2
K	0.7 yr^{-1}
ϕ'	2.576
W_∞	128 g
t_0	- 0.01702

LW Parameters

	Male	Female	Combined
a	0.0729	0.0149	0.00559
b	2.306	2.859	3.19265
r	0.86	0.96	
n	199	201	

ELEFAN Parameters

File Name	Drussel990001.lfq
R_n	
SS/SL	

Selection Parameters	
L-25	
L-50	
L-75	
L_c / L_∞	
t_c	

Maturity Parameters	
L_m	14.1
Peak breeding	
L_m / L_∞	0.61
Generation time (t_g=t_{opt})	1.33 yr

Population Parameters

Z	2.67
CI of Z	
M	1.34
F	1.36
E (F/Z)	0.5
L_{opt}	14.2
F_{opt}	1.34

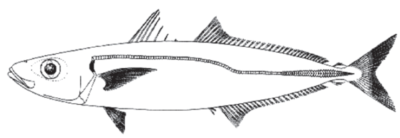
Ecopath Parameters

P/B	2.67
Q/B	17.19
Ar	2.46
Biomass	461 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.88

Remarks: Data from Prathibha Rohit (unpubl)
All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Decapterus macrosoma*
Common Name : Short fin Scad (Tidimba)
Family : Carangidae



Centre : Mangalore	
Period : 2000-01	
Gears Exploiting : **TR**, **PS**	
Fleet : MDF, PS	
Habitat Area : 27.000 km^2	
Ecological Grouping : 11 Small Bentho-pelagics	
Data Source : **Other**	
Annual Ave Catch : 1185 t	

Growth Parameters

L_{max}/t_{max}	22.8
L_r	14
L’	
L_{mean}	
L_∞	23.8
K	0.75 yr^{-1}
ϕ’	2.6287
W_∞	127
t_0	- 0.014995

LW Parameters

	Male	Female	Combined
a	0.0225	0.0242	0.00649
b	2.668	2.647	3.11737
r	0.93	0.93	
n	135	150	

ELEFAN Parameters

File Name	Dmacro9900.lfq
R_n	
SS/SL	

Selection Parameters	
L-25	
L-50	
L-75	
L_c/L_∞	
t_c	

Maturity Parameters	
L_m	14.4
Peak breeding	
L_m/L_∞	0.6
Generation time (t_g=t_{opt})	1.25 yr

Population Parameters

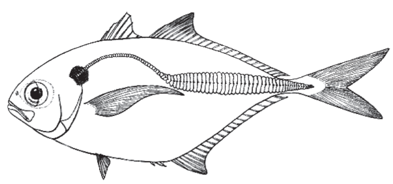
Z	1.78
CI of Z	
M	1.42
F	0.36
E (F/Z)	0.2
L_{opt}	14.6
F_{opt}	0.36

Ecopath Parameters

P/B	1.78
Q/B	17.57
Ar	2.57
Biomass	5923 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.88

Remarks: Data from Prathibha Rohit (unpubl)
All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Caranx kalla (=Alepes djeddaba)*	Centre : Mangalore
Common Name : Shrimp Scad (Thakatte)	Period : 2000-01
Family : Carangidae	Gears Exploiting : **TR**, **PS**
	Fleet : MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 11 Small Bentho-Pelagics
	Data Source : Other
	Annual Ave Catch : 2586 t

Growth Parameters		LW Parameters	Male	Female	Combined
L_{max}/t_{max}	16		Male	Female	Combined
L_r	6.3	a	0.0635	0.0085	0.0488
L'		b	2.871	3.026	2.816
L_{mean}		r	0.92	0.93	
L_∞	16.8	n	196	361	
K	0.7 yr^{-1}	**ELEFAN Parameters**			
φ'	2.2957	File Name			
W_∞	137.7 g	R_n			
t_0	0.018597	SS/SL			

Selection Parameters	
L-25	
L-50	
L-75	
L_c/L_∞	
t_c	

Maturity Parameters	
L_m	10.5
Peak breeding	Dec-Jan/May-Jun
L_m/L_∞	0.63
Generation time (t_g=t_{opt})	1.14 yr

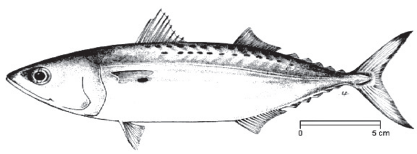
Population Parameters	
Z	2.67
CI of Z	
M	1.69
F	0.98
E (F/Z)	0.36
L_{opt}	9.31
F_{opt}	0.950

Ecopath Parameters	
P/B	2.67
Q/B	17.72
Ar	2.70
Biomass	7183 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.88

Remarks: Data from literature (Jayabalan). Diet composition data through project
All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Rastrelliger kanagurta*	Centre : Mangalore
Common Name : Indian mackerel	Period : 1999-2001
Family : Scombridae	Gears Exploiting : TR, GN, PS, AS
	Fleet : MDF, DGN, PS, AS
	Habitat Area : 27000 km^2
	Ecological Grouping : 12 Mackerel
	Data Source : **Other**
	Annual Ave Catch : 25526 t



Growth Parameters

L_{max}/t_{max}	28.8
L_r	6.6
L'	18.5
L_{mean}	21.7
L_∞	30.2
K	1.55 yr^{-1}
ϕ’	3.1475
W_∞	334 g
t_0	-0.0039

LW Parameters

	Male	Female	Combined
a			0.0050
b			3.261
r			0.99
n			266

ELEFAN Parameters

File Name	Macksm.lfq
R_n	0.122
SS/SL	21/ 180

Selection Parameters	
L-25	17.3
L-50	18.1
L-75	18.6
L_c/L_∞	0.62
t_c	0.6 yr

Maturity Parameters	
L_m	17.8
Peak breeding	Jun-Aug
L_m/L_∞	0.59
Generation time (t_g=t_{opt})	0.7 yr

Population Parameters

Z	6.24
CI of Z	5.58-6.89
M	2.43
F	3.80
E (F/Z)	0.61
L_{opt}	19.8
F_{opt}	4.0

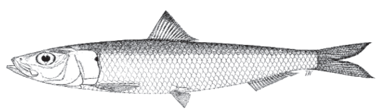
Ecopath Parameters

S	S
P/B	6.24
Q/B	62.36
Ar	3.82
Biomass	41846 t
EE	0.67
Feeding type	Herbivore
Trophic level	2.00

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sardinella longiceps*
Common Name : Indian oil sardine (Buthai)
Family : Clupeidae



Centre : Mangalore	
Period : 1999-2001	
Gears Exploiting : **TR**, **PS**, AS	
Fleet : MDF, PS, AS	
Habitat Area : 27000 km^2	
Ecological Grouping : 13 Clupeids	
Data Source : **Other**	
Annual Ave Catch : 31711 t	

Growth Parameters	
L_{max}/t_{max}	22.3
L_r	11.5
L'	14.0
L_{mean}	16.6
L_∞	23.3
K	1.6 yr^{-1}
ϕ'	2.9388
W_∞	94 g
t_0	-0.0037

LW Parameters	Male	Female	Combined
a			0.0211
b			2.699
r			0.93
n			259

ELEFAN Parameters	
File Name	Slong97, 98, 99. lfq (3files)
R_n	0.126
SS/SL	7/ 17.75

Selection Parameters	
L-25	11.7
L-50	13.6
L-75	14.2
L_c/L_∞	0.58
t_c	0.54 yr

Maturity Parameters	
L_m	14.1
Peak breeding	Jun-Aug
L_m/L_∞	0.61
Generation time (t_g=t_{opt})	0.64 yr

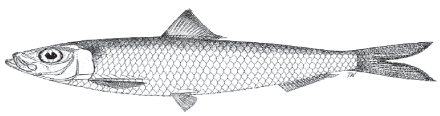
Population Parameters	
Z	6.36
CI of Z	5.61-7.11
M	2.67
F	3.69
E (F/Z)	0.58
L_{opt}	15
F_{opt}	3.7
Recruit period	Apr-May

Ecopath Parameters	
P/B	6.36
Q/B	68.49
Ar	2.96
Biomass	54675 t
EE	0.95
Feeding type	Herbivore
Trophic level	2.95

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sardinella gibbosa* Common Name : Gold stripe sardine (Erabai) Family : Clupeidae	Centre : Mangalore
	Period : 1999-2001
	Gears Exploiting : **TR**, **PS**, AS
	Fleet : SDF, PS, AS
	Habitat Area : 27000 km^2
	Ecological Grouping : 13 Clupeids
	Data Source : **Other**
	Annual Ave Catch : 2003 t



Growth Parameters

L_{max}/t_{max}	19.3
L_r	10.8
L'	15.5
L_{mean}	16.6
L_∞	21.1
K	1.4 yr^{-1}
ϕ’	2.7947
W_∞	83 g
t_0	-0.0062

LW Parameters

	Male	Female	Combined
a			0.0158
b			2.784
r			0.984
n			

ELEFAN Parameters

File Name	Sgibb97m, 98m, 99 m.lfq(3 files)
R_n	
SS/SL	

Selection Parameters	
L-25	14.0
L-50	14.6
L-75	15.2
L_c/L_∞	0.69
t_c	0.84 yr

Maturity Parameters	
L_m	12.9
Peak breeding	Oct-Mar
L_m/L_∞	0.61
Generation time (t_g=t_{opt})	0.7 yr

Population Parameters

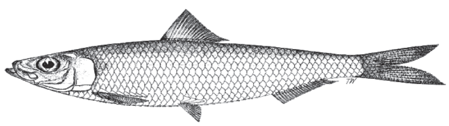
Z	6.88
CI of Z	6.11-7.64
M	2.52
F	4.36
E (F/Z)	0.63
L_{opt}	13.2
F_{opt}	4.29

Ecopath Parameters

P/B	6.88
Q/B	63.25
Ar	2.41
Biomass	3180 t
EE	0.95
Feeding type	Herbivore
Trophic level	2.95

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Sardinella fimbriata* Common Name : Fringe scale sardine (Erabai) Family : Clupeidae	Centre : Mangalore
	Period : 1999-2001
	Gears Exploiting : **TR**, **PS**
	Fleet : SDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 13 Clupeids
	Data Source : **Other**
	Annual Ave Catch : 155 t

Growth Parameters			LW Parameters		Male	Female	Combined
	L_{max}/t_{max}	21.3			Male	Female	Combined
	L_r	10.8		a			0.00971
	L'	15.0		b			2.908
	L_{mean}	16.1		r			0.988
	L_∞	21.7		n			
	K	1.3 yr^{-1}		**ELEFAN Parameters**			
	ϕ'	2.7869		File Name	Sfimb97, 98, 99.lfq		
	W_∞	75 g		R_n			
	t_0	-0.0078		SS/SL			

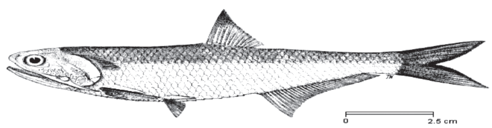
Selection Parameters		**Maturity Parameters**	
L-25	13.3	L_m	13.3
L-50	14.1	Peak breeding	
L-75	14.6	L_m / L_∞	0.61
L_c / L_∞	0.65	Generation time (t_g=t_{opt})	0.74 yr
t_c	0.8 yr		

Population Parameters			Ecopath Parameters		
	Z	6.11		P/B	6.11
	CI of Z	5.43-6.79		Q/B	14.99
	M	2.38		Ar	1.18
	F	3.73		Biomass	253 t
	E (F/Z)	0.61		EE	0.95
	L_{opt}	13.5		Feeding type	Carnivore
	F_{opt}	3.72		Trophic level	2.95

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Thryssa mystax* Common Name : Moustached thryssa Family : Engraulidae	Centre : Mangalore
	Period : 1999-2000
	Gears Exploiting : **TR**, **PS**
	Fleet : SDF/MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 13 Clupeids
	Data Source : **Project**
	Annual Ave Catch : 1536 t



Growth Parameters

L_{max}/t_{max}	20.8
L_r	10.0
L'	15.0
L_{mean}	16.6
L_∞	22.7
K	1.3 yr^{-1}
ϕ'	2.8260
W_∞	89 g
t_0	-0.0077

LW Parameters

	Male	Female	Combined
a	0.0084	0.0072	
b	2.954	3.019	
r	0.91	0.92	
n	184	199	

ELEFAN Parameters

File Name	Tmyst00, 01 lfq (2files)
R_n	0.177
SS/SL	13.75

Selection Parameters	
L-25	13.4
L-50	14.3
L-75	14.9
L_c / L_∞	0.63
t_c	0.76 yr

Maturity Parameters	
L_m	13.8
Peak breeding	
L_m / L_∞	0.61
Generation time (t_g=t_{opt})	0.74 yr

Population Parameters

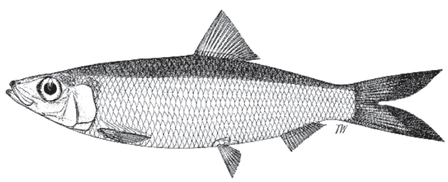
Z	5.77
CI of Z	5.15-6.38
M	2.35
F	3.42
E (F/Z)	0.59
L_{opt}	14.2
F_{opt}	3.38

Ecopath Parameters

P/B	5.77
Q/B	15.62
Ar	1.57
Biomass	2603 t
EE	0.95
Feeding type	Carnivore
Trophic level	2.95

Remarks: All length measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Dussumieria acuta* Common Name : Rainbow sardine (Seeriande) Family : Clupeidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **TR**, **PS**
	Fleet : SDF, MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 13 Clupeids
	Data Source : **Project**
	Annual Ave Catch : 168 t

Growth Parameters

L_{max}/t_{max}	20.5
L_r	11
L'	14
L_{mean}	16.5
L_∞	23.4
K	0.98 yr^{-1}
ϕ'	2.7297
W_∞	96.4 g
t_0	-0.0164

LW Parameters

	Male	Female	Combined
a	0.0092	0.0104	0.0098
b	2.938	2.894	2.916
r	0.98	0.97	
n	162	177	

ELEFAN Parameters

File Name	Dacutasm.lfq
Rn	0.293
SS/SL	2/13.25

Selection Parameters	
L-25	11.4
L-50	12.3
L-75	12.8
L_c/L_∞	0.53
t_c	0.75 yr

Maturity Parameters	
L_m	14.2
Peak breeding	
L_m/L_∞	0.61
Generation time (t_g=t_{opt})	0.93

Population Parameters

Z	2.26
CI of Z	1.68-2.83
M	1.94
F	0.32
E (F/Z)	0.14
L_{opt}	14.1
F_{opt}	0.32
Recruit period	Jul-Oct

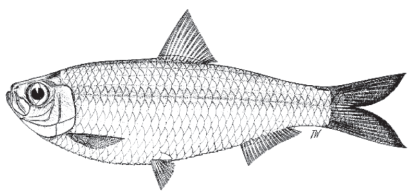
Ecopath Parameters

P/B	2.26
Q/B	18.24
Ar	2.47
Biomass	1196 t
EE	0.95
Feeding type	Carnivore
Trophic level	2.95

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Esculosa thoracata* Common Name : White Sardine (Bolanjir) Family : Clupeidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **TR**, **PS**, **AS**
	Fleet : SDF, MDF, PS, AS
	Habitat Area : 27000 km^2
	Ecological Grouping : 13 Clupeids
	Data Source : **Project**
	Annual Ave Catch : 776 t



Growth Parameters

L_{max}/t_{max}	12.4
L_r	7.5
L'	10.8
L_{mean}	11.1
L_∞	13.9
K	1.6 yr^{-1}
ϕ'	2.4909
W_∞	28.41
t_0	-0.0043

LW Parameters

	Male	Female	Combined
a	0.0061	0.0064	
b	3.213	3.187	
r	0.93	0.92	
n	178	149	

ELEFAN Parameters

File Name	Kcovalsm.lfq
Rn	0.201
SS/SL	2/ 10.3

Selection Parameters	
L-25	10.3
L-50	10.6
L-75	10.8
L_c / L_∞	0.76
t_c	0.89

Maturity Parameters	
L_m	8.9
Peak breeding	
L_m / L_∞	0.64
Generation time (t_g=t_{opt})	0.58 yr

Population Parameters

Z	17.41
CI of Z	13.12-21.71
M	3.08
F	14.33
E (F/Z)	0.82
L_{opt}	8.5
F_{opt}	14.03

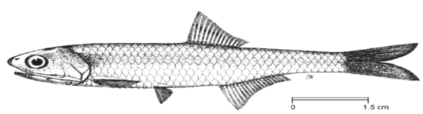
Ecopath Parameters

P/B	17.41
Q/B	55.55
Ar	2.2
Biomass	947 t
EE	0.95
Feeding type	Detritivore
Trophic level	2.95

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Stolephorus devisi*
Common Name : Devis anchovy (Kollatharu)
Family : Engraulidae



Centre : Mangalore

Period : 1999-2001

Gears Exploiting : **TR**, **PS**

Fleet : SDF, MDF, PS

Habitat Area : 27000 km^2

Ecological Grouping : 14 Anchovies

Data Source : **Project**

Annual Ave Catch : 3677 t

Growth Parameters

L_{max}/t_{max}	10.3
L_r	5.5
L'	8.0
L_{mean}	8.7
L_∞	10.4
K	1.6 yr $^{-1}$
ϕ’	2.2298
W_∞	7 g
t_0	-0.0047

LW Parameters

	Male	Female	Combined
a	0.0311	0.0354	
b	2.307	2.249	
r	0.87	0.82	
n	216	228	

ELEFAN Parameters

File Name	Sdevi98m, 99m.lfq (2files)
R_n	
SS/SL	

Selection Parameters	
L-25	7.1
L-50	7.6
L-75	8.0
L_c / L_∞	0.73
t_c	0.82 yr

Maturity Parameters	
L_m	6.8
Peak breeding	Oct-Dec, Apr-May
L_m / L_∞	0.66
Generation time (t_g=t_{opt})	1.0 yr

Population Parameters

Z	4.13
CI of Z	3.49-4.78
M	3.35
F	0.78
E (F/Z)	0.19
L_{opt}	6.1
F_{opt}	0.8

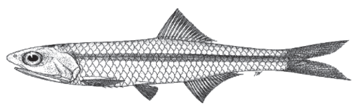
Ecopath Parameters

P/B	4.13
Q/B	82.16
Ar	1.11
Biomass	19354 t
EE	0.95
Feeding type	Herbivore
Trophic level	3.49

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Stolephorus buccaneeri* Common Name : Buccaneer anchovy (Kollatharu) Family : Engraulidae	Centre : Mangalore
	Period : 1999-2001
	Gears Exploiting : **TR**, **PS**
	Fleet : SDF, MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 14 Anchovies
	Data Source : **Project**
	Annual Ave Catch : 517 t



Growth Parameters

L_{max}/t_{max}	10.8
L_r	4.3
L'	8.5
L_{mean}	9.2
L_∞	11.7
K	0.88 yr^{-1}
ϕ’	2.0009
W_∞	11 g
t_0	-0.0252

LW Parameters

	Male	Female	Combined
a			0.0121
b			2.7579
r			0.971
n			

ELEFAN Parameters

File Name	Sbaca98m,99m.lfq (2file)
R_n	0.27
SS/SL	1/ 8.25

Selection Parameters	
L-25	7.8
L-50	8.2
L-75	8.6
L_c/L_∞	0.74
t_c	1.35 yr

Maturity Parameters	
L_m	7.6
Peak breeding	
L_m/L_∞	0.65
Generation time (t_g=t_{opt})	1.52 yr

Population Parameters

Z	4.06
CI of Z	3.17-4.96
M	2.19
F	1.87
E (F/Z)	0.46
L_{opt}	6.4
F_{opt}	1.87

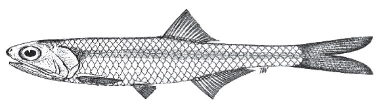
Ecopath Parameters

P/B	4.06
Q/B	25.18
Ar	1.81
Biomass	1123 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.49

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Stolephorus bataviensis* Common Name : Spot faced Anchovy (Kollatharu) Family : Engraulidae	Centre : Mangalore
	Period : 1999-2001
	Gears Exploiting : **TR**, **PS**
	Fleet : SDF, MDF, PS
	Habitat Area : 27000 km^2
	Ecological Grouping : 14 Anchovies
	Data Source : **Other**
	Annual Ave Catch : 587 t



Growth Parameters

L_{max}/t_{max}	11.3
L_r	4.3
L'	8.5
L_{mean}	9.6
L_∞	13.0
K	1.4 yr^{-1}
ϕ'	2.374
W_∞	14 g
t_0	-0.0071

LW Parameters

	Male	Female	Combined
a			0.00000728
b			2.978
r			0.954
n			182

ELEFAN Parameters

File Name	SDbatv98, 99sm.lfq (2fil)
R_n	
SS/SL	

Selection Parameters	
L-25	7.9
L-50	8.7
L-75	9.6
L_c/L_∞	0.67
t_c	0.8 yr

Maturity Parameters	
L_m	8.4
Peak breeding	
L_m/L_∞	0.64
Generation time (t_g=t_{opt})	1.2 yr

Population Parameters

Z	5.67
CI of Z	3.2-8.14
M	2.88
F	2.79
E (F/Z)	0.49
L_{opt}	7.7
F_{opt}	2.8

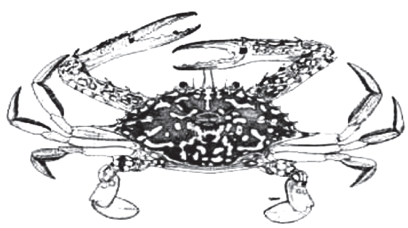
Ecopath Parameters

P/B	5.67
Q/B	20.65
Ar	1.09
Biomass	1197 t
EE	0.95
Feeding type	Carnivore
Trophic level	3.49

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Portunus pelagicus* Common Name : Reticulate crab (Denji) Family : Portunidae	Centre : Mangalore
	Period : 1999 - 2000
	Gears Exploiting : **TR**
	Fleet : MDF/SDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 15 Crabs & lobsters
	Data Source : **Other**
	Annual Ave Catch : 526 t



Growth Parameters

L_{max}/t_{max}	19.7
L_r	
L'	
L_{mean}	
L_∞	20.8
K	1.14 yr^{-1}
ϕ'	2.7055
W_∞	874 g
t_0	-0.0115

LW Parameters

	Male	Female	Combined
a			0.00000975
b			3.4323
r			0.98
n			217

ELEFAN Parameters

File Name	Pelag00F, 00M.lfq (2files)
R_n	
SS/SL	

Selection Parameters	
L-25	6.98
L-50	7.11
L-75	8.61
L_c / L_∞	0.34
t_c	0.36 yr

Maturity Parameters	
L_m	12.7
Peak breeding	Aug-May
L_m / L_∞	0.61
Generation time (t_g=t_{opt})	0.81 yr

Population Parameters

Z	6.63
CI of Z	5.12-8.17
M	2.18
F	4.45
E (F/Z)	0.67
L_{opt}	12.7
F_{opt}	4.43

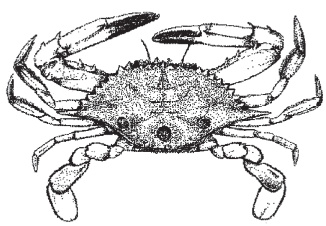
Ecopath Parameters

P/B	6.63
Q/B	8.5
Ar	
Biomass	784 t
EE	0.780
Feeding type	Omnivore
Trophic level	2.89

Remarks: Data from literature Sukumaran *et.al*
All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Portunus sanguinolentus* Common Name : Spotted crab (Denji) Family : Portunidae	Centre : Mangalore
	Period : 1999 - 2000
	Gears Exploiting : **TR**
	Fleet : MDF/SDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 15 Crabs and Lobsters
	Data Source : **Other**
	Annual Ave Catch : 730 t



Growth Parameters		LW Parameters		Male	Female	Combined
L_{max}/t_{max}	19.3					
L_r			a			0.000051
L'			b			3.0295
L_{mean}			r			0.98
L_∞	20.3		n			170
K	0.99 yr^{-1}		**ELEFAN Parameters**			
φ'	2.5757		File Name	Psang00M, 00F.lfq (2Files)		
W_∞	418 g		R_n			
t_0	-0.0166		SS/SL			

Selection Parameters	
L-25	7.98
L-50	8.93
L-75	9.51
L_c/L_∞	0.44
t_c	0.57 yr

Maturity Parameters	
L_m	12.5
Peak breeding	Aug-May
L_m/L_∞	0.61
Generation time (t_g=t_{opt})	0.89 yr

Population Parameters	
Z	6.2
CI of Z	5.44-6.96
M	2.03
F	4.17
E (F/Z)	0.67
L_{opt}	12.1
F_{opt}	4.1

Ecopath Parameters	
P/B	6.2
Q/B	8.5
Ar	
Biomass	1083 t
EE	0.78
Feeding type	Omnivore
Trophic level	2.89

Remarks: Data from literature Sukumaran *et.al*
All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Metapenaeus monoceros* Common Name : Speckled prawn (Mandetti) Family : Penaeidae	Centre : Mangalore
	Period : 2000-01
	Gears Exploiting : **TR**
	Fleet : MDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 16 Shrimps
	Data Source : **Project**
	Annual Ave Catch : 2267 t

Growth Parameters

L_{max}/t_{max}	18.5
L_r	7.0
L'	9.5
L_{mean}	12.0
L_∞	19.5
K	2.7 yr^{-1}
ϕ’	3.0114
W_∞	60 g
t_0	-0.0003

LW Parameters

	Male	Female	Combined
a	0.0039	0.0061	
b	3.24	3.084	
r	0.98	0.98	
n	96	105	

ELEFAN Parameters

File Name	Monoc00m, 00f, 01m, 01f. lfq (4 files)
R_n	0.205
SS/SL	4/ 130

Selection Parameters	
L-25	7.9
L-50	8.6
L-75	9.1
L_c / L_∞	0.44
t_c	0.22 yr

Maturity Parameters	
L_m	12.0
Peak breeding	Nov-Dec
L_m / L_∞	0.62
Generation time (t_g=t_{opt})	0.4 yr

Population Parameters

Z	7.97
CI of Z	7.37-8.57
M	3.95
F	4.02
E (F/Z)	0.5
L_{opt}	13.1
F_{opt}	4.0

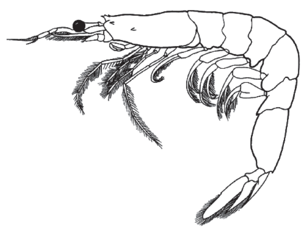
Ecopath Parameters

P/B	7.97
Q/B	19.2
Ar	
Biomass	4534 t
EE	0.947
Feeding type	Omnivore
Trophic level	3.02

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Acetes indicus* Common Name : Paste shrimp (Shamae yeti) Family : Sergestidae	Centre : Mangalore
	Period : 1999 - 2000
	Gears Exploiting : **TR**
	Fleet : SDF
	Habitat Area : 27000 km^2
	Ecological Grouping : 16 Shrimps
	Data Source : **Other**
	Annual Ave Catch : 97 t



Growth Parameters		LW Parameters	Male	Female	Combined
L_{max}/t_{max}	3.8				
L_r		a			
L'		b			
L_{mean}		r			
L_∞	4.0	n			
K	1.6 yr^{-1}	**ELEFAN Parameters**			
φ'	1.4082	File Name			
W_∞		R_n			
t_0	-0.0060	SS/SL			

Selection Parameters	
L-25	
L-50	
L-75	
L_c/L_∞	
t_c	

Maturity Parameters	
L_m	2.9
Peak breeding	
L_m/L_∞	0.72
Generation time ($t_g = t_{opt}$)	0.68 yr

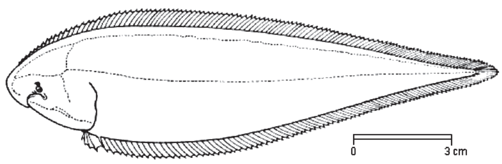
Population Parameters	
Z	5.39
CI of Z	
M	4.26
F	1.13
E (F/Z)	0.21
L_{opt}	2.12
F_{opt}	1.132

Ecopath Parameters	
P/B	5.39
Q/B	
Ar	
Biomass	460 t
EE	0.95
Feeding type	Detritivore
Trophic level	3.02

Remarks: Literature data
All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name	: *Cynoglossus macrostomus*
Common Name	: Malabar tongue Sole (Nangu)
Family	: Cynoglossidae



Centre : Mangalore
Period : 2000-01
Gears Exploiting : **TR**
Fleet : MDF, SDF
Habitat Area : 27000 km^2
Ecological Grouping : 17 Benthic omnivores
Data Source : **Project**
Annual Ave Catch : 9569 t

Growth Parameters

L_{max}/t_{max}	16.5
Lr	10.5
L'	11
L_{mean}	13
L_∞	17.5
K	2.0 yr^{-1}
ϕ'	2.781
W_∞	27.1
t_0	-0.0015

LW Parameters

	Male	Female	Combined
a			0.0266
b			2.420
r			0.88
n			199

ELEFAN Parameters

File Name	Cmacro990001.lfq
Rn	0.353
SS/SL	3/ 145

Selection Parameters	
L-25	9.2
L-50	10.1
L-75	11
L_c/L_∞	0.58
t_c	0.43

Maturity Parameters	
L_m	10.9
Peak breeding	Oct-Jan
L_m/L_∞	0.62
Generation time (t_g=t_{opt})	1.819 yr

Population Parameters

Z	7.74
CI of Z	4.37-11.1
M	3.35
F	4.39
E (F/Z)	0.57
L_{opt}	11.23
F_{opt}	3.115

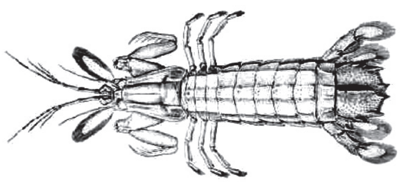
Ecopath Parameters

P/B	7.74
Q/B	39.61
Ar	0.01
Biomass	16787 t
EE	0.98
Feeding type	Detritivore
Trophic level	2.55

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Species Life History Sheet

Species Name : *Oratosquilla nepa*	Centre : Mangalore
Common Name : Mantis Shrimp (Pooche)	Period : 2000-01
Family : Stromateidae	Gears Exploiting : **TR**
	Fleet : SDF/MDF
	Habitat Area : 27,000 km^2
	Ecological Grouping : 17 Benthic omnivores
	Data Source : **Project**
	Annual Ave Catch : 12805 t



Growth Parameters

L_{max}/t_{max}	11.4
L_r	4.0
L'	7.5
L_{mean}	8.9
L_∞	12.1
K	1.9 yr^{-1}
ϕ'	2.4443
W_∞	18 g
t_0	-0.0022

LW Parameters

	Male	Female	Combined
a	0.017	0.0136	
b	2.786	2.884	
r	0.97	0.97	
n	107	109	

ELEFAN Parameters

File Name	Onepa2.lfq
R_n	0.28
SS/SL	1/ 7.3

Selection Parameters	
L-25	6.3
L-50	7.3
L-75	7.3
L_c/L_∞	0.60
t_c	0.50 yr

Maturity Parameters	
L_m	7.8
Peak breeding	
L_m/L_∞	0.65
Generation time (t_g=t_{opt})	0.5 yr

Population Parameters

Z	5.27
CI of Z	3.86-6.68
M	3.59
F	1.68
E (F/Z)	0.32
L_{opt}	7.42
F_{opt}	1.69

Ecopath Parameters

P/B	5.27
Q/B	19.2
Ar	
Biomass	40017
EE	0.98
Feeding type	Detritivore
Trophic level	2.55

Remarks: All measurements in cm; for expansion of abbreviations please see glossary/acronyms

Glossary / Acronyms

a	multiplicative term in a length/weight relationship
abiotic	referring to non-living structures, substances, factors, environments, etc
apex predator	a fish at the top of the food chain, relying on smaller fishes for food. the complex of living organisms and environmental conditions that function as a unit. Biocenosis plus biotope
A_r	aspect ratio of caudal fin of fish. $A_r = h^2/s$ where h, height of caudal fin of fish and s, surface area
AS	Artisanal Gear, operated mainly during monsoon season (indigenous) fishing undertaken by peoples native to an area.
ascendancy index	information content of an ecosystem. The product of total system throughput (T) times an index of the average mutual information
asymptotic length	length the fish in a stock would attain if they were to grow for an infinitely long period. Not the largest observed size of a species (L_∞).
asymptotic weight	a parameter of the von Bertalanffy Growth Function, q.v., expressing the mean weight the fish in a stock would attain if they were to grow for an infinitely long period (W_∞).
b	exponent of a length-weight relationship
benthos	organisms which live on the bottom of a water body, in it or near it.
benthic infauna	benthic animals living in the soft bottom or substrate
biomass	or standing stock. The total weight of a group (stock) of living organisms in an area at a particular time
bloom	a rapid and localised increase in the density of plankton resulting from a nutrient-rich habitat. The nutrients may come from upwelling, mixing or pollution and the bloom can kill fish populations through toxins or oxygen depletion.
Bi	Biomass of group (i). dimension = UNIT
cannibalism	eating members of one's own species
catch	the number or weight of fish caught by a fishery, by fishing gear or by angling. May be the total amount caught, only the amount landed, or not kept but released. Usually expressed in terms of wet weight.
combination vessel	a vessel capable of more than one type of fishing, e.g. longliner/dragger, midwater trawler/purse seiner, bottom trawler/purse seiner.
connectance index	for a given food web, the ratio of the number of actual links to the number of possible links.
continental shelf	the area of gently sloping sea bottom from the shore out to a depth of about 200 metres. It may be only a few kilometres offshore where the sea floor descends rapidly to great depths or may be extensive and form an accessible habitat for many commercial fishes.
continental slope	the steeply sloping sea bottom from 200 to 2000 metres (or 100-300 m to 1400-3200 m) and 3-6°C. Average angle of slope is 4° with a maximum about 20° near the upper margin.

Ci	Catch of group (i) UNIT time-1
density dependence	the dependence of a factor influencing population dynamics (such as survival rate or reproductive success) on population density. The effect is usually in the direction that contributes to the regulative capacity of a stock
detritus	debris, disintegrated material or particulate material that enters into an aquatic system. If derived from decaying organic matter it is organic detritus.
DGN/GN	drift gill net Boats, gillnet fleet
discard	the part of a fish catch that is thrown overboard, but which may be of important ecological or commercial value. Also the act of throwing fish overboard. The discard typically consists of “non-target” species, damaged specimens or undersized specimens. The fish may be alive or dead, whole or in parts. Estimates of discards are made by observers and logbook records. Also called discarded catch. Discarding lower value fish to increase the value of a catch is called high grading.
dynamic pool model	analytical yield-per-recruit types of fisheries models describing how growth, recruitment and mortality interact, resulting in biomass and yields.
DCij,	The fraction that prey j constitutes in predator i’s food intake; is weighted over species, sizes and seasons included in a box. UNIT time-1
DC (N1,i)	Diet composition of detritus box, Dimensionless
E	exploitation rate; E = F/Z
ecotrophic efficiency	= EE - The ratio between what flows into it and what flows out of. It is that part of production that is exported from or is eaten within the system (t . km^{-2} . $year^{-1}$)
electivity	express the food preferences of consumers. electivities scale from -1 (total avoidance) over 0 (non-selective feeding) to 1 (exclusive feeding). The electivity is calculated as standardized forage ratio.
ecosystem	the complex of living organisms and environmental conditions that function as a unit. Biocenosis plus biotope.
ecosystem maturity	a number of statistics describing an ecosystem as a whole which can be of use for assessing the status of an ecosystem, e.g., to express its state of maturity
effort	the total fishing gear in use for a specified period of time; when two or more kinds of gear are used, they must be adjusted to some standard type before being added.
equilibrium	when fishing and natural mortality, exploitation pattern, growth and recruitment do not change from year to year; when such factors have been in effect long enough to affect all ages for the whole exploited life. Also called steady state.
equilibrium yield	the yield in weight taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next (Ricker, 1975). Also called sustainable yield, equivalent sustainable yield. No stock is really in balance with fishing effort because effort cannot be maintained at the same level and the stock is always changing in response to environmental variables.
productivity/primary productivity	a measure of the capacity of a biological system, the amount of fish supported or produced by a given area in a given time. Also used as a measure of the efficiency with which a biological system converts energy into growth and production. A highly productive stock of fishes has high birth, growth and mortality rates resulting in high turnover and production to biomass ratios. Such a stock can be exploited fully and can recover more easily if depleted.

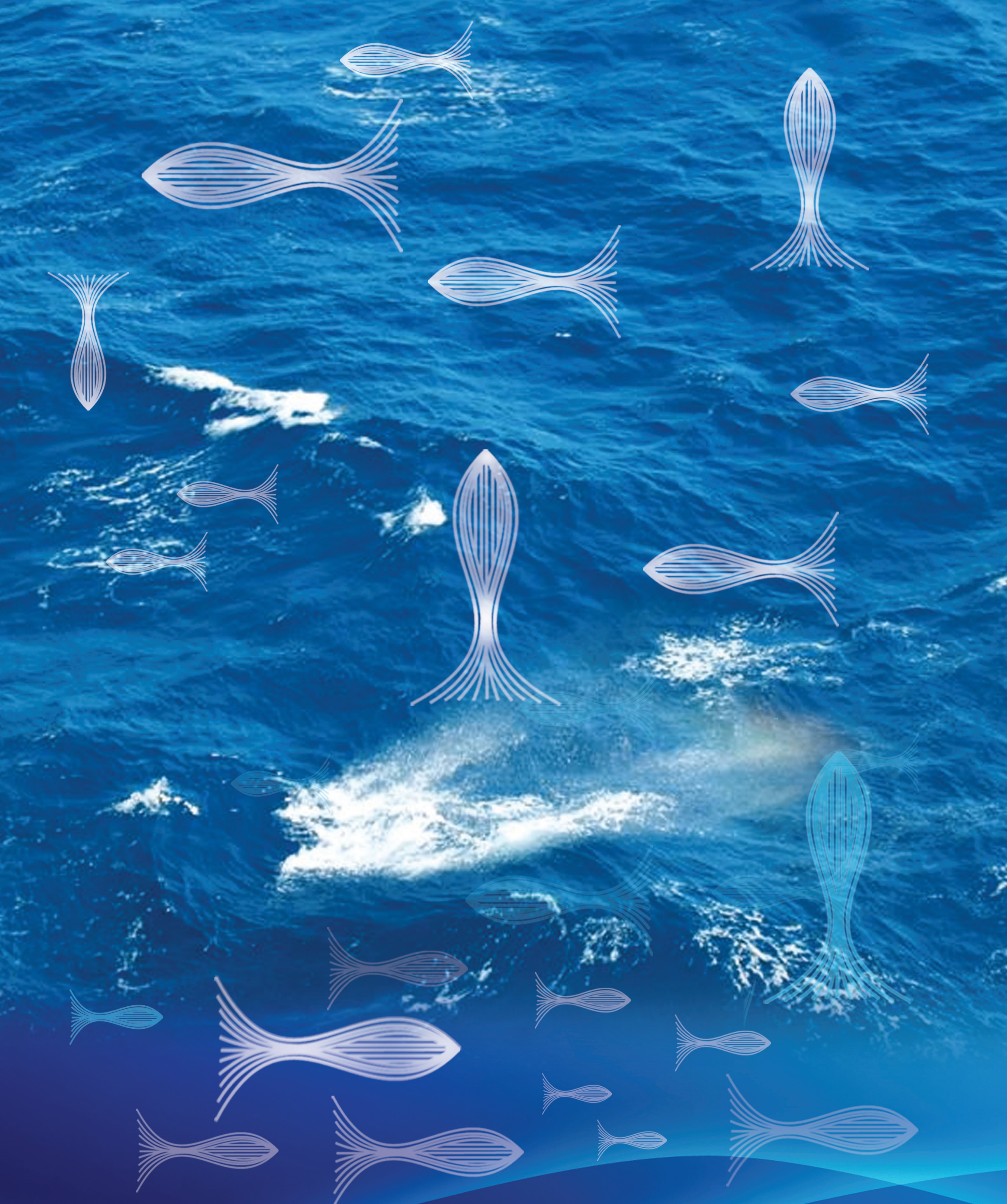
exports	sum of fishery catches plus migration to/from adjacent ecosystems
exploitation rate	the proportion of a population at the beginning of a given time period that is caught during that time period (usually on a yearly basis). A catch in a year of 10 fish out of a stock of 100 is a 10% exploitation rate. Also the ratio of fish caught to total mortality (= F/Z when fishing and natural mortality take place concurrently (Ricker, 1975)). Also called rate of exploitation. Abbreviated as E.
EEi	Ecotrophic Efficiency is production that goes to predation and catches (including exports); same as (1 - other mortality)
Ei	The coefficient for other exports than fishery, time-1
F	Instantaneous rate of fishing mortality (mortality due to fishing)
fishing effort	effective fishing effort, abbreviated as f or f (Ricker, 1975).
fishery model	a representation of a fishery, usually simplified and may be mathematical
flow diagram	graphical representation of trophic flow from one group to another in an ecosystem model
Fmax or F_{max}	the rate of fishing mortality for a given exploitation pattern, rate of growth, and natural mortality that results in the maximum yield per recruit; the point that defines growth overfishing. This mortality would give the maximum catch year after year. $F_{0.1}$ is often preferred as F_{max} is difficult to estimate
FMSY or F_{MSY}	the fishing mortality rate which, if applied constantly, would result in maximum sustainable yield. Can be estimated from simple biomass-aggregated production models or from age-structured models that include a stock-recruitment relationship. Reality applies, howver, and as the ocean conditions change a constant fishing mortality of F_{MSY} would give varying catches and eventually overfishing would result. A 2/3F_{MSY} is used to avoid overfishing. Fishing at this level means fishermen use only two-thirds of the effort needed to achieve maximum sustainable yield but they catch 80-90% of the MSY. Their catch rate is higher.
forage	the diet of a fish species.
F_{opt}	optimum (effective) fishing effort corresponding to fMSY, Used as biological reference point
generation time	T_g, the average age of parents at the time their young ones are born. In most fishes L_{opt} is the size class with the maximum egg production $t_g = t_0$-ln (1-L_{opt}/L_{∞}) / K.
GN	Gill net
gonadal products	the products by sexual organs, ovary and testis, producing the primary sexual products (eggs and sperm).
gross efficiency of the fishery	ratio between the total catch (landing + discards) and the total primary production in the system. Value will be higher for systems with fishery harvesting fish low in the food chain than fisheries concentrate on apex predators
growth model	a mathematical description or representation of the size of a living organisms at its various ages, e.g. the Von Bertalanffy growth model.
GEi	Gross efficiency (of food conversion); Dimensionless
habitat	the place a species lives, defined by necessary biological and physical parameters, e.g. tidal pool, marsh, reef, continental shelf
homogenous	uniform

K	curvature parameter of the VBGF (increase in weight of a fish per year, divided by the initial weight).
km	kilometre (0.621 mi).
L-25	length at which 25% of the fish will be vulnerable to the gear (left hand selection)
L-50	length at which 50% of the fish will be vulnerable to the fishing gear
L-75	length at which 75% of the fish will be vulnerable to the fishing gear
L_{∞}	asymptotic length, i.e., the (mean) length the fish of a given stock would reach if they were to grow forever
L_c	mean length of fish at first capture; equivalent to L_{50}
L_c/L_{∞}	gear selection parameter
L_m	mean length first maturity (or massive maturation)
L_m/L_{∞}	Ratio of length at first maturity to asymptotic length indicating relative reproductive costs.
L_{max}	maximum length reached by the fish of a given stock, may also be predicted from the largest specimens of several samples using the extreme value theorem
L_{mean}	mean length of fish computed from L' upward in catch curve
L_{opt}	the length class with the highest biomass in an unfished population, where the number of survivors multiplied with their average weight reaches a maximum (Beverton 1992)
L_r	mean length at first recruitment
landings	the weight of a catch as fish or fish products brought to a wharf or beach. Also called landed weight. Note that the catch is different and may include discards
length Frequency	a breakdown of the different lengths of a kind of fish in a population or sample.
length-weight relationship	mathematical formula for the weight of a fish in terms of its length. When only one is known, the formula can be used to determine the other.
linear relationship	used to described the variation of one variable as a liner function of another variable, e.g., total length and body weight of a fish
M	Instantaneous rate of natural mortality, i.e., due to all causes except fishing
maturity	fish of a given age/size capable of reproduction; attainment of first spawning
mechanised fishing sector	organized sector which uses crafts fitted with in-board engines, such as purse siener, trawler; mechanized fishing is banned during monsoon season.
MDF	multi-Day Fishing Fleet, Trawlers which undertake voyages lasing two days or more
mortality rate	the rate at which the numbers in a population decrease with time due to various causes. The proportion of the total stock (in numbers) dying each year is the annual mortality rate. To facilitate calculations, mortality is expressed as an exponential rate (called instantaneous rate) thus Nt/N0 = e-Z = e-(M+F) in which Nt/N0 is the survival rate, M the natural mortality rate, F the fishing mortality rate, and Z the total mortality rate (of deaths due to predation or disease).
MOi	Other mortality coefficient; time-1
M2i	Predation mortality of (i); time-1
n	number of items in a sample

nekton	organisms of relatively large size which have fairly strong locomotory powers (as compared to plankton) and swim in the water column independent of currents, e.g. most adult fishes.
net system production	or yield is the difference between total primary production and total respiration. System production will be large in immature systems and close to zero in mature ones.
niche overlap	an overlap in resource requirements by two species; is an overlap indexwhich explains how a single prey (food) is shared between two predators
overhead	the difference between development capacity (C) and ascendancy (A). provides limits on he increase in ascendancy and reflect the strength in reserve from which it can draw to meet unexpected perturbations.
overcapitalization	where the amount of harvesting capacity in a fishery exceeds the amount needed to harvest the desired amount of fish at least cost. Too many boats, too much fishing effort. May be addition of new technology rather than new boats
over-exploitation	rate of exploitation where the resource stock is drawn down below the size that would, on average, support the long term maximum potential yield of the fishery.
P/B	equivalent to total mortality under steady state, when von Bertalanffy growth and exponential mortality are used
pelagic season	the September-November season when pelagic fishes like sardine and mackerel are exploited by gears specially designed to harvest them (purse seine)
population dynamics	the study of fish populations and how fishing mortality, growth, recruitment, and natural morality affect them over time.
potential yield	the yield of fishes estimated to be available for exploitation.
	the yield in weight taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next (Ricker, 1975). Also called sustainable yield, equivalent sustainable yield. Abbreviated as YE or Y_E. No stock is really in balance with fishing effort because effort cannot be maintained at the same level and the stock is always changing in response to environmental variables
primary consumer	a fish that feeds on the lowest level of a community's food web, namely plants. Also called first-level consumer.
production model	a population model that describes how biomass changes from year to year or how biomass changes in equilibrium as a function of fishing mortality. Three or four simple parameters are used in a deterministic model. Production models are used primarily in simple data situations where total catch and effort data are available but age-structured data is unavailable or less reliable
PS	purse seine- a seine used to encircle a school of fish in open water. It is set at speed from a large, powered vessel and the other end is anchored by a small boat. A purse line at the bottom of the net allows it to be closed like a purse.
P/B	(Equation 8) Production/biomass ratio of (i). Equals the total mortality; time-1
Pi	Production rate of (i). UNIT time-1
PPi	Proportion of production of (i) that is attributed to primary production 0 PP 1 > 0 for consumers; Dimensionless
Q/B	Ratio of consumption over biomass where consumption is the intake of food by a group over the time period expressed as /year

Qi	Consumption rate of (i); UNIT time-1
r	product-moment correlation coefficient
recruit	an individual fish that has moved into a certain class, such as the spawning class or fishing-size class through growth, migration, etc.
R_n	goodness of fit index of the ELEFAN I routine (=$10^{ESP/ASP}$/10)
resilience	capacity of a natural system such as a fisheries community or ecosystem to recover from heavy disturbance such as intensive fishing.
respiration	a flow (flows) of mass or energy that is not directed toward, nor could be used by any other box (es). When Carbon is used as currency respiration appears as CO_2
Schaefer model	the basic form of production model in which the relation between yield and effort takes the form of a symmetric parabola.
SDF	single-Day Fishing Fleet, Trawlers which make daily trips
SL	starting length; one of two coordinates used to locate a growth curve in the ELEFAN I routine
size-at-first-maturity	length or weight at maturity. Maturity is defined as minimal size attained at maturity or the size at which 50% of the fish at that size are mature.
spawning stock biomass (SSB)	the total weight of the fish in a stock that are old enough to spawn; the biomass of all fish beyond the age or size class in which 50% of the individuals are mature. May be used instead of measuring egg production).
SS	starting sample - the other coordinate used to locate a growth curve in the ELEFAN I routine
standing stock	biomass; weight of a stock. May apply to a part of the stock such as spawning fish, fish in a particular area or at a particular time stochastic = having components affected by random variability, e.g. future recruitments in a fishery are projected with a stochastic component (random variables) to allow for unexplained effects.
steady state population	is a theoretical construction never occurring in reality. Can be approximated by averaging time series data over longer periods if there are no major changes in biomass or size
stock	the part of a fish population which is under consideration from the point of view of actual or potential utilization; stock (noun) = a distinct genetic population, a population defined by movement pattern, part of a population potentially harvestable, i.e. an assessment or management unit, or a quantity of fish from a given area; usually isolated from other stocks of the same species and so self-sustaining. May be a total or a spawning stock.
summer monsoon	the south-west monsoon occurring during the June-September period
surplus production model	an estimate of the catch in a given year and the change in stock size. The stock size could increase or decrease depending on new recruits and natural mortality. A surplus production model estimates the natural increase in fish weight or the sustainable yield
sustainable yield	the yield (in weight or number) taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next. Also called equilibrium yield, equivalent sustainable yield.
	abbreviation for tonne (metric ton, 1000 kg, 2204.62 pounds (lb), 0.984 long

system omnivory index	average omnivory index of all consumers weighted by the logarithm of each consumer's food intake, is a measure of how the feeding interactions are distributed between the sexes.
t	tonnes
total length	length from the anterior-most part of the head to the tip of either lobe of the caudal fin when that fin is normally splayed.
total system throughput (T)	sum of all flows into and from the boxes in an ecosystem including imports and exports of usable materials or energy (i.e., catches or emigration) expressed as t./km^2/year
t_0	the age the fish would have had at length zero if they had grown always according to the VBGF
t_c	mean age at first capture, corresponding to l_c
t_{max}	longevity, approximate maximum age that fish of a given population would reach. $t_{max} = t_0 + 3/K$
trophic	pertaining to nutrition.
trophic level	(Troph),Classification of organisms or natural communities according to their place in the food web, trophic = 1+ mean troph of the food items
upwelling	an upward movement of cold, nutrient-rich water from the ocean depths, often associated with great production of fish and fisheries. For fisheries, the most important types are wind-induced coastal upwelling where the upward movement is a consequence of wind stress (along shore) and Eckman transport (offshore).
virtual population analysis	an algorithm for computing historical fishing mortality rates and stock sizes by age or length, based on data on catches, natural mortality, and certain assumptions about mortality for the last year and last age group. Essentially reconstructs the history of each cohort or year class over its life in a fishery, assuming that the observed catches are known without error. Abbreviated as VPA. Also called cohort analysis.
winter monsoon	The North-East monsoon which occurs during November-January period
W_∞	asymptotic weight, i.e., the (mean) weight the fish of a given stock would reach if they were to grow forever
yield	catch in weight. Catch and yield are often used interchangeably. Amount of production per unit area over a given time. A measure of production. The sustainable yield is the quantity of fish which can be taken from a stock (usually on an annual basis) without severely depleting or eliminating that stock.
yield-per-recruit analysis	analysis of how growth, natural mortality, and fishing interact to determine the best size of the fish at which to start fishing them, and the most appropriate level of fishing mortality. The yield-per-recruit models do not consider the possibility of changes in recruitment (and reproductive capacity) due to change in stock size. They also do not deal with environmental impacts.
Z	Instantaneous rate of total mortality (the sum of natural and fishing mortalities)
Φ'	Phi-prime, i.e., length based index of growth performance ($\Phi' = \log_{10}(K) + 2\log_{10}(L_\infty)$)



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