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Review of Resource Assessment Information on Small Pelagic Fish Stocks in Coastal Marine Waters of Sri Lanka

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Abstract

This paper summarizes the resource assessment information available for the small pelagic marine fish resources of Sri Lanka. Almost all the studies available in the literature had been carried out since early 1980's possibly with the development of techniques for tropical fish stock assessment. A summary of the population dynamic parameter estimates on growth, mortality, recruitment, fecundity and sexual maturity is presented with the limited yield assessment estimates. Most of the stock assessment studies are based on the length frequency data collected from the commercial fisheries and assessments have been carried out with various assumptions. Few studies based on age determination using daily growth rings are available. Yield assessments have been carried out mostly using the predictive Thompson & Bell model and assuming localised distribution. A comprehensive stock assessment of the small pelagics carried out recently shows that a marginal increase in yield of small pelagics could be obtained by doubling the fishing effort which would result in low catch rates for individual fishermen and thereby less profit.

Introduction

Around 40% of the coastal marine fish production in Sri Lanka constitutes of small pelagics. According to the statistics of the Ministry of Fisheries and Aquatic Resources Development, in 1996 the total small pelagic fish production was around 65,000 mt. Although the traditional beach seining was the only single fishery that contributed to the production of small pelagics in the era before the motorization of the fishing industry, in 1980's more than 80% of the small pelagic production was from the gillnets (10-102mm mesh) operated by the motorised Fibre Reinforced Plastic (FRP) boats and motorised and non-motorised traditional crafts (Karunasinghe & Dayaratne 1986). A purse seine fishery, developed along the south -west coastal waters in 1980's targeted the small pelagic resources which produced around 615 mt annually, was banned in 1992 (Dayaratne & Sivakumaran 1994). Presently, the small pelagics are caught mainly by the small meshed gillnets with a minor contribution from beach seines and other incidental gear.

Resource assessment of small pelagics in Sri-Lanka has been carried out only since early 1980's probably with the development of tropical fish stock assessment methodologies. Further, the resource assessment studies on small pelagic fish resources are limited to a few species, although a large number of small pelagics are caught in Sri Lankan waters. Among the few species that have been studied for stock assessment,

most of the studies are on sardines (Clupeidae) particularly the spotted sardine (*Amblygaster sirm*) which is the most common sardine in all the areas. Almost all these studies have utilised length based stock assessments techniques except for a few studies carried out by age determination using daily growth rings. Majority of the length based studies are on samples collected from the small meshed gillnet fishery. The important population dynamics parameters studied include those on growth, mortality, recruitment, length-weight relationships, size and age at maturity, fecundity etc. This paper briefly reviews the published and unpublished information on these aspects.

Growth Parameter estimates

Growth parameter estimates available for 11 species of small pelagics are given in Table 1. Seven separate estimates have been made for *A. sirm*, out of which six estimates are based on length frequency data and one on daily growth increments. A wide range of parameter estimates are seen even for the same species from the same area. Most of the length based assessment on fish samples collected from gillnet catches have not been corrected for selection and hence would have biased the estimate made for growth parameters. This bias would have been overcome to some extent in areas where a wide range of mesh sizes are used at the same time where the fishery brings in a representative sample of the population. Table 2 provides the length weight relationships of some small pelagics.

Mortality estimates

The total mortality coefficients for all the species recorded (Table 3) have been estimated from a linearized catch curve based on length composition data using the computer software package Compleat ELEFAN (Gayanilo et al. 1988). The natural mortality coefficients have all been estimated using Pauly's empirical formula where the growth parameters and the ecosystem temperature are important input parameters (Pauly 1980). Because of the wide range of growth estimates for the same species a range of values are seen for the natural mortality coefficient.

Recruitment

Recruitment patterns for all the species studied have been based on length frequency assessments using Compleat ELEFAN computer package. Almost all species seem to follow the same pattern with two recruitment peaks per year (Table 4).

Gear Selectivity

All available information on the size and age at 50% selection have been estimated using the catch curve analysis. For species caught by the small meshed gillnets, the estimates made for the 50% selection assumes a "knife-edge" selection in the catch curve analysis used in the Compleat ELEFAN package (Tables 6 and 7). As the selectivity of the gillnets is different, such estimates has to be taken with caution.

Table 1. Asymptotic fork length (L_∞ in cm) and Von Bertalanffy Growth Coefficient (K per yr) of small pelagics. LF = Length Frequency Analysis; DGR = Analysis of Daily Growth Rings.

Species	Growth Parameters		Method	Location (Period)	Source
	L_∞	K			
Amblygaster sirm	24.75 24.80	0.95 0.95	LF	Negombo (1980-81) Negombo (1983-84)	Siddeek et al (1985)
Amblygaster sirm	23.8	0.95	LF	South coast	Karunasinghe (1986)
Amblygaster sirm	22.5 22.75 23.5	2.15 2.06 1.93	LF	South west (1985) South west (1986) South west (1987)	Dayaratne (1990 a)
Amblygaster sirm	25.0 24.9 25.8	1.10 1.20 1.48	LF	West coast (1984-85) West coast (1985-86) West coast (1986-87)	Karunasinghe & Wijeyaratne (1991a)
Amblygaster sirm	24.6	1.3	LF	South west (1991-1992)	Dayaratne & Sivakumaran (1994)
Amblygaster sirm	25.8	1.06	LF	North west (1990-1992)	Dayaratne et al (1995)
Amblygaster sirm	22.87	2.38	DGR	Negombo (1980-1981)	Dayaratne & Gjosaeter (1986)
Sardinella gibbosa	12.98	4.4	DGR	Negombo (1980-1981)	Dayaratne & Gjosaeter (1986)
Sardinella gibbosa	17.0	2.2	LF	Negombo (1979-1980)	Dayaratne (1997)
Sardinella albella	12.2	5.43	DGR	Negombo (1980-1981)	Dayaratne & Gjosaeter (1986)
Sardinella longiceps	16.3	2.77	DGR	East coast (1981)	Dayaratne & Gjosaeter (1986)
Rastrelliger kanagurta	36.0	1.7	LF	South west (1991-1992)	Dayaratne & Sivakumaran (1994)
Decapterus macarellus	41.2	0.8	LF	South west (1991-1992)	Dayaratne & Sivakumaran (1994)
Selar crumenophthalmus	34.75	0.5	LF	South west (1991-1992)	Dayaratne & Sivakumaran (1994)
Nematalosa nasus	39.2	0.9	LF	North west (1990-1992)	Dayaratne et al (1995)
Hirundichthys oxycephalus	28.5	1.1	LF	North west (1990-1992)	Dayaratne et al (1995)
Leiognathus brevirostris	13.8	0.9	LF	North west (1991-1993)	Jayawardena (1997)
Stolephorus heterolobus	8.62	4.02	DGR	South west (1987-1988) South west (1987-1988)	Dayaratne (1990b)

Table 2. Length-weight relationships of some small pelagics.

Species	Sex	Length (L) - Weight (W) relationship (W in g and L in cm)	Source
Amblygaster sirm	Female Male	Log W= 3.02 Log L - 1.01 (r^2= 0.99, n= 115) Log W= 2.92 Log L - 1.01 (r^2 = 0.99 , n=132) Log W= 2.52 Log L - 1.03 (r^2 = 0.97, n= 22)	Karunasinghe (1990)
Sardinella gibbosa	Females Males	Log W= 2.58 Log L - 1.62 (r^2 = 0.92, n= 71) Log W= 2.46 Log L - 1.05 (r^2 = 0.90, n= 131)	Dayaratne (1997)
Leiognathus brevirostris	Females Males	Log W = 3.17 Log L -1.01 Log W = 2.89 Log L - 1.02	Jayawardena (1997)
Hirundichthys coromandelensis	Female Male	Log W = 2.12 Log L - 1.98 Log W = 2.81 Log L - 1.09	Jinadasa (1972)

Table 3. Mortality coefficients (yr^{-1}) of some small pelagics (Z = Total mortality coefficient; F= Fishing mortality coefficient; M = Natural mortality coefficient).

Species	Mortality coefficients			Location (Period)	Source
	Z	F	M		
Amblygaster sirm	4.1	2.0	2.1	West coast (1980)	Dayaratne (1985)
Amblygaster sirm	2.39	0.96	1.43	Negombo (1980-81)	Siddeek et al. (1985)
	3.07	1.64	1.43	Negombo (1983-84)	
Amblygaster sirm	0.82	82	1.82	South coast (1983-84)	Karunasinghe (1986)
Amblygaster sirm	2.75	1.45	1.30	West coast	Karunasinghe & Wijevaratne (1991a)
Amblygaster sirm	4.23	1.04	3.19	South west (1985)	Dayaratne (1990a)
	5.41	2.32	3.09	South west (1986)	
	5.56	2.62	2.94	South west (1987)	
Amblygaster sirm	3.17	0.97	2.24	South west (1990-92)	Dayaratne & Sivakukmaran (1994)
Amblygaster sirm	2.4	0.46	1.94	North west (1990-92)	Dayaratne et al. (1995)
Rastrelliger kanagurta	3.99	1.59	2.4	South west (1991-92)	Dayaratne & Sivakumaran (1994)
Decapterus macarelus	3.79	2.38	1.41	South west (1991-92)	Dayaratne & Sivakumaran (1994)
Selar crumenophthalmus	1.6	0.51	1.09	South west (1991-92)	Dayaratne & Sivakumaran (1994)
Sardinella gibbosa	10.3	6.8	3.5	West coast	Dayaratne (1997)
Nematalosa nasus	2.23	1.5	0.54	North west (1990-92)	Dayaratne et al. (1995)
Hirundichthys oxycephalus	3.09	1.16	1.93	North west (1990-92)	Dayaratne et al. (1995)
Leiognathus brevirostris	4.4	2.4	2.1	North west (1991-93)	Jayawardena (1997)

Table 4. Seasonality of recruitment as determined by length-based assessment methods.

Species	Recruitment peaks	Source
Amblygaster sirm	Two recruitment peaks per year	Dayaratne (1989) Karunasinghe & Wijevaratne (1991a)
Amblygaster sirm	Two recruitment peaks per year	Karunasinghe (1986)
Amblygaster sirm	Two recruitment peaks per year	Jayawardena (1997)
Sardinella gibbosa	Two recruitment peaks per year	Dayaratne (1984)
Leiognathus brevirostris	Two recruitment peaks per year	Jayawardena (Pers. Comm.)

Table 5. Length at 50% recruitment to the fishery as determined by length-based assessment methods.

Species	Fishery	Size at 50% recruitment (cm)	Period of study	Source
A. sirm	Gillnet	18.75	1984-1985	Karunasinghe (1990)
		19.32	1985-1986	
		14.95	1986-1987	

Table 6. Length and age at 50% selection

Species	Fishing gear	Length at 50% selection	Age at 50% selection	Source
Amblygaster sirm	Gillnets 28 mm mesh Gillnets 30 mm mesh		0.4 yr 0.5 yr	Dayaratne (1985)
Amblygaster sirm	Gillnets;25-38 mm mesh	16.17 cm		Karunasinghe & Wijeyaratne (1991a)
Amblygaster sirm	Gillnets;28-38 mm mesh	16.45 cm		Karunasinghe (1986)
Amblygaster sirm	Gillnets 30-45 mm mesh	19.5 cm		Dayaratne & Sivakumaran (1994)
Amblygaster sirm	Purse seine	19.01 cm	11months	Dayaratne (1990 a)
Amblygaster sirm	Purse seine	20.02 cm		Dayaratne & Sivakumaran (1994)
Amblygaster sirm	Beach seine	3.9 cm		Dayaratne & Sivakumaran (1994)
Amblygaster sirm	Gillnets;30-50 mm	19.6 cm		Jayawardena (Pers Comm.)
Decapterus macrelles	Gillnets 63-102 mm mesh	29.5 cm		Dayaratne & Sivakumaran (1994)
Decapterus macrelles	Purse seine	10.1 cm		Dayaratne & Sivakumaran (1994)
Decapterus macrelles	Ring nets	27.6 cm		Dayaratne & Sivakumaran (1994)
Selar crumenophthalmes	Gillnets;63-102 mm mesh	22.3 cm		Dayaratne & Sivakumaran (1994)
Selar crumenophthalmes	Purse seine	11.2 cm		Dayaratne & Sivakumaran (1994)
Auxis thazaard	Gillnets,63-102 mm mesh	23.7 cm		Dayaratne & Sivakumaran (1994)
Auxis thazard	Ring nets	25.6 cm		Dayaratne & Sivakumaran (1994)
Rastrelliger kanagurta	Gillnets 63-102 mm mesh	21.7 cm		Dayaratne & Sivakumaran (1994)
Rastrelliger kanagurta	Purse seine	11.0 cm		Dayaratne & Sivakumaran (1994)
Rastrelliger kanagurta	Beach seine	6.9 cm		Dayaratne & Sivakumaran (1994)
Nematalosa nasus	Gillnets,32-50 mm mesh	19.4 cm		Dayaratne *et al* (1995)
Hirundichthys oxycephalus	Gillnets;29-48 mm mesh	20.6 cm		Jayawardena (Pers Comm.)
Leiognathus brevirostris	Trawl nets; 20mm cod end	8.72 cm		Jayawardena (1997)

Sexual Maturity

Unlike the growth and mortality estimates, the information available on sexual maturity is sparse although these parameters are equally important in providing management recommendations on mesh size regulations (Tables 8 and 9).

Spawning

Spawning seasons of some small pelagic species have been estimated using the gonadosomatic indices and by back calculating the birth-dates using the age estimated by daily growth rings. Almost all the species studied have indicated two spawning seasons, the major peak coincides with the beginning of the south-west monsoon and the other with the beginning of the North-east monsoons (Table 10).

Yield Assessments

Yield assessments available in the literature are those made for specific fisheries in particular areas. Except in one study (Karunasinghe, 1990) where yield assessment has been made using Surplus Production Model, all other studies have used the Thompson & Bell (1934) yield predictive method in estimating the Maximum Sustainable Yields. Recently, a comprehensive yield assessment for small pelagics in the western, south-western and southern waters has been carried out using Surplus Production Models and Thompson & Bell (1934) models (Table 11).

Table 7. Gillnet selectivity factors

Species	Gillnet selectivity	Method	Source
Amblygaster sirm	L_{50}=5.53 x Mesh size L_{50}=5.48 x Mesh size (when L in cm)	Gillnets comparison; fish length /girth measurements	Dayaratne (1988a)
Amblygaster sirm	Selection factor ranged from 5.11 - 6.03	Gillnets comparisons	Karunasinghe & Wijeyaratne (1991b)

Table 8. Length and age at 50% sexual maturity

Species	Sex	Length at 50% maturity	Age at 50% maturity	Method	Source
Amblygaster sirm	Females Males	15.0 cm 15.1 15.9 cm	10.2 mth 11.5 mth	Gonad incides	Karunasinghe (1990)
Leiognathus brevirostris	Females Males	18.1 cm 18.2 7.98 cm		Gonad indices	Jayawardena (1997)

Table 9. Fecundity estimates

Species	Fecundity	Method	Source
Amblygaster sirm	Between 55,000 and 95,000 eggs for the size range 16.0 - 20.0 cm	Egg counts	Karunasinghe (1990)
Leiognathus brevirostris	Between 12,337 and 18,333 eggs for the size range 9.5cm and 11.5 cm	Egg counts	Jayawardena (1997)

Table 10. Seasonality of spawning

Species	Spawning seasons	Method	Source
Amblygaster sirm	Protracted spawning with peak in April-June	Back-dating from birthdate	Dayaratne (1984)
Amblygaster sirm	Peak spawning in February-May	Gonad indices	Karunasinghe (1990)
Sardinella albella	Two spawning periods major peak in February-March and minor peak in October-December	Back-dating from birthdate	Dayaratne (1984)
Sardinella gibbosa	Two spawning periods major peak in May-July and minor peak in December	Back-dating from birthdate	Dayaratne (1984)
Dusumiera acuta	Two spawning periods	Back-dating from birthdate	Dayaratne (1989)
Ilisha melanostoma	Two periods	Back-dating from birthdate	Dayaratne (1989)
Escualosa thoracata	Two periods	Back-dating from birthdate	Dayaratne (1989)
Opisthopterus tardoore	Two spawning periods	Back-dating from birthdate	Dayaratne (1989)
Chanos chanos	Spawning period March-May	Back-dating from birthdate	Dayaratne (1988 b)
Leiognathus brevirostris	Two spawnings one in February-March the other August	Gonadosomatic Index	Jayawardena (1997)

Table 11. Yield assessments available for small pelagic species (T & B - Thompson and Bell (1934) Model; SM - Schaefer (1954) Model; FM - Fox (1970) Model)

Fishery	Area	Model used	Species	MSY (tonnes)	Effort Multiplier	Source
Purse Seine	South west	T & B	*A. sirm* *R. kanagurta* *S. crumenophthalmus* *D. macrellus*	1002 42 107 115	4 5 0 16 0 26 0 06	Dayaratne & Sivakumaran (1994)
Gillnet	South west	T & B	*A. thazard* *R. kanagurta* *D. macrellus* *S. crumenophthalmus*	5435 703 116 378	1 8 1 1 8 6 6 2	Dayaratne & Sivakumaran (1994)
Ring net	South west	T & B	*A. thazard* *D. macrellus*	9207 100	31	Dayaratne & Sivakumaran (1994)
Gillnet	West	SM	*A. sirm*	3512		Karunasinghe (1990)
Gillnet	North west	T & B	*A. sirm*	3737	4 6	Jayawardena (Pers Comm.)
Gillnet	North west	T & B	*H. oxycephalus*	4890	1 16	Jayawardena (Pers Comm.)
Trawl net	North west	T & B	*L. brevirostris*	287	0 82	Jayawardena (1997)
Gillnet, Purse seine and Beach seine	North west, west, south west and south	T & B	*A. sirm*	30,500*	2 0	Sanders & Dayaratne (in press)
Gillnet, Purse seine and Beach seine	North west, west, south west and south	T & B	Small pelagic	58,000	2 0	Sanders & Dayaratne (in press)
Gillnet, Purse seine and Beach seine	North west, west, south west and south	SM	Small pelagic	30,000	2 0	Sanders & Dayaratne (in press)
Gillnet, Purse seine and Beach seine	North west, west, south west and south	FM	Small pelagic	53,000	2 0	Sanders & Dayaratne (in press)

Discussion

Although there is a general belief that the fish resources in the marine coastal waters of Sri Lanka are exploited to the maximum, there is no sufficient scientific information on the assessment of resources to validate such a statement. The small pelagics resource which contributes to around 65% of the total coastal marine fish production has not been comprehensively assessed in the past. Only recently, such assessment has been attempted based on catch data as well as on information on a single species (*Amblygaster sirm*) (Sanders & Dayaratne, in press). Due to the multispecies/multigear nature of the coastal fisheries in Sri Lanka, the fish stock assessment has been a difficult task. Several assumptions have to be made during the stock assessment process which may or may not be valid. Among the large number of small pelagic species, only a few have been assessed for stock status and almost all these assessments are made for localised areas assuming that there are localised populations. It is not certain whether the small pelagic species found in the coastal waters around Sri Lanka belong to the same stock or whether there are several localised stocks. Stock identification by means of allozyme and DNA variations, as attempted by Karunasinghe (1995), would be helpful in understanding the nature of these populations.

Another observation that could be made on the review of the population dynamic parameters of the small pelagics is the wide variation of the parameter estimates even for the same species from the same location. Some of these differences are due to the different stock assessment techniques/ methodologies used which have their own limitations. However, in reality whatever the technique is used the end result should be similar. In Sri-Lanka, more than 80% of the small pelagics are caught in small meshed gillnets and therefore any sampling bias would definitely affect the parameter estimates. This has been minimised in some studies where samples from gill nets with a wide range of mesh size have been collected and in some cases corrections have been made for the gillnet selectivity. Use of independent estimates for growth and mortality estimates are essential as these parameters form the basis for any stock assessment. Attempts should be made to estimate the growth of fish using daily growth rings wherever possible and use methods other than Pauly's formula (Pauly 1980) for the estimation of natural mortality.

The review on yield assessments of small pelagics shows that the few studies carried out for small pelagics have used the length based Thompson & Bell predictive model which is more appropriate for short lived species. Most of these studies have shown that there is a possibility to increase the present fishing effort on small pelagic resources but resulting in only a marginal increase in total yield. Such increase in fishing effort would definitely result in a decrease in catch rates of individual fishing units making the individual fishing operations less profitable. Possibilities of increasing the fishing effort for some species such as flying fish in the North west, and pony fish in the Portugal Bay are evident. More resource assessment studies are needed for other small pelagics such as Indian Mackeral (*Rastrelliger* spp.), Scad mackerals (*Decapterus* spp., *Sellar* spp.), other sardines (*Sardinella* spp.) Anchovies (*Stolephorus* spp.), Baracudas (*Sphyraena* spp.) and Half beaks (Hemiramphids).

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