REPRODUCTIVE BIOLOGY AND LARVAL REARING OF *HIPPOCAMPUS KUDA*, AND THE TAXONOMY OF SEAHORSES (*HIPPOCAMPUS* SPP.) ALONG THE SOUTHERN COAST OF INDIA.

Thesis submitted in partial fulfillment
of the requirements
for the degree of

Ph. D. (Mariculture)

by

K.R.SALIN, M. F. Sc.
(PhD 92)

ICAR CIFE

CENTRAL INSTITUTE OF FISHERIES EDUCATION
(Deemed University)
Indian Council of Agricultural Research
Versova, Mumbai-400 061

SEPTEMBER, 2003

Dedicated to
Dr. Amanda J. Vincent,
the Rolex laureate
for her continuing efforts to save
the legendary horses of the sea
from extinction

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

POST BOX NO. 1603, ERNAKULAM, COCHIN - 682 014

Telephone: 394867/ 394407 Ext. ; Telegram: CADALMIN Ernakulam

CERTIFICATE

Certified that the thesis entitled **REPRODUCTIVE BIOLOGY AND LARVAL REARING OF *HIPPOCAMPUS KUDA* AND THE TAXONOMY OF SEAHORSES (*HIPPOCAMPUS* SPP.) ALONG THE SOUTHERN COAST OF INDIA** is a record of independent, bona-fide research work carried out by **Mr. K. R. SALIN** during the period of study from September 1998 to September 2003 under our supervision and guidance for the degree of **Doctor of Philosophy (Mariculture)** and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

Major Advisor/ Chairman

(Dr. T. M. Yohannan)
Principal Scientist (Rtd.)
Calicut Research Centre of CMFRI

Advisory Committee

Dr. E. V. Radhakrishnan
Head, Crustacean Division, CMFRI

Dr. K C George
Principal Scientist
P N P Division,
C.M.F.R.I

Mr. K. K Philippose
Scientist (SG)
Calicut Research Centre of C.M.F.R.I

Mr. Narayana Kurup
Principal Scientist
I.I.S.R, Calicut.

18.05.04

DECLARATION

I hereby declare that the thesis entitled **REPRODUCTIVE BIOLOGY AND LARVAL REARING OF *HIPPOCAMPUS KUDA*, AND THE TAXONOMY OF SEAHORSES (*HIPPOCAMPUS* SPP.) ALONG THE SOUTHERN COAST OF INDIA** is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

K.R.SALIN
Ph. D. Student
Central Institute of
Fisheries Education

Kochi
01.09.2003

ACKNOWLEDGEMENTS

Dr. T. M. Yohannan, Principal Scientist (Rtd.), Calicut Research Centre of CMFRI, and the Major Advisor / Chairman, has been an incessant source of inspiration and guidance during the course of my work. His encouragement and support was tremendous. I gratefully acknowledge my indebtedness to him for the valuable advice and timely guidance for conducting the experiments and preparation of this thesis.

My sincere thanks are due to **Dr. Mohan Joseph Modayil**, Director, CMFRI, for providing me the necessary facilities that have enabled the completion of this work. I am also indebted to **Dr. M. Devaraj**, and **Dr. V. N. Pillai**, former Directors, CMFRI for their encouragement.

The advisory committee members, **Dr. E. V. Radhakrishnan**, Head, Crustacean Division, CMFRI, **Mr. K. K. Philippose**, Scientist (SG), Calicut Research Centre of CMFRI, **Dr. K. C. George**, Principal Scientist, PNP Division, CMFRI and **Mr. K. Narayana Kurup**, Principal Scientist, IISR, Calicut, were all encouraging and supportive right from the beginning of the work. I am deeply obliged to them.

The guidance, direction and wise counselling by **Dr. R. Paul Raj**, Principal Scientist and Officer-in-charge, PGPM, during my work has contributed a lot to the completion of this work. I am immensely thankful to him. My sincere thanks are also due to **Dr. C. Susheelan**, Principal Scientist (Rtd.) and former Officer-in-charge, PGPM, CMFRI, for his support.

I also acknowledge with thanks the guidance and advise given by **Dr. Amanda J. Vincent** and **Dr. Sara A. Lourie**, Project Seahorse, McGill University, Quebec, Canada, especially for contributing specific ideas and valuable comments during the planning and preparation of this work.

Words fail to acknowledge the support by **Dr. C. Mohanakumaran Nair**, Associate Professor, College of Fisheries, Kochi, who has been the moving spirit and source of inspiration behind this thesis. Without his sustained support and enduring encouragement by meticulous scrutiny of the manuscript, critical remarks and befitting suggestions, it would have been impossible for me to complete this work.

My sincere thanks are also due to **Mr. T. M. Sankaran**, Associate Professor and Head, Dept. of Management studies, who showed a keen interest in my work and advised me on the statistical design, analysis of data and planning of the experiments.

The generous help rendered by my friends **Mr. Jayaseelan**, M. A. V. Singhi Company, Mandapam, and **Mr. Joseph Neethi**, Redlin Aquarium, Chennai during my field visits and collection of specimens is gratefully acknowledged.

The support given by the staff of various sections of CMFRI, Kochi, and Calicut Research Centre of CMFRI during my work is thankfully acknowledged. I also wish to place on record my sincere gratitude to the officers-in-charge and staff of the Mandapam and Madras Regional Centres of CMFRI, and the Minicoy Centre of CMFRI, for providing me all the help and facilities during the field visits and collection of specimens.

Thanks are also due to my friend **Mr. Sudhakar Babu** and my associate **Mr. A. M. Ajithkumar**, for their generous co-operation in type setting and final layout, without which it would have been difficult to give a good shape to this thesis.

The financial assistance given by ICAR during the course of my work in the form of Institutional fellowship is also gratefully acknowledged.

Finally, but very significantly, I owe a great deal to the enormous patience and support shown by the fisherfolks of Tamil Nadu and Kerala, and the many collection agents who provided some of the most important inputs to this work. The co-operation of the two seahorse dealers, who wished to be anonymous, are also acknowledged with thanks, for providing some of the key information that had gone into the planning and execution of this work.

Kochi
1.9.2003

K. R. SALIN

सारांश

भारत के पाक उपसागर और मान्नार खाडी में समुद्री घोडे की एक सुसंगठित मात्स्यिकी तथा विपणन विद्यमान है. दक्षिण तट से समुद्री घोडे की छह जातियों जैसे *हिप्पोकाम्पस बोर्बोनिएन्सिस* उमेरिल 1870, *हिप्पोकाम्पस स्पिनोसिसिमस* वेबर 1913, *हिप्पोकाम्पस कुडा ब्लीकर 1852, हिप्पोकाम्पस फिसकस* रप्पेल 1838, *हिप्पोकाम्पस ट्रिमाकुलेटस* लीच 1814 और *हिप्पोकाम्पस गट्टुलाटस* क्युवीर 1829 को पहचान किये थे. वर्ष 2001 के दौरान तोण्डि से 18.25 मेट्रिक टन या 26,48,179 समुद्री घोड़ों को आकलित किया था. भारत से समुद्री घोडों के विपणन की मात्रा सुखाये गये समुद्री घोडे केलिए 9.75 मेट्रिक टन आकलित किया था. केरल के क्वयलॉन तट पर 1.6 मेट्रिक टन (5,61,418 समुद्री घोडे) का अवतरण होने पर भी इसकी ऑंकडा संगठित विपणन में शामिल नहीं किया गया है. तोण्डी में प्रमुख जाति (27.96%) एच. *बोर्बोनिएन्सिस* देखा गया और अन्य थी एस. *स्पिनोसिसिमस (22.14%), एच.कुडा* (20.0%), *एच.ट्रइमाकुलाटस* (14%), *एच. फसकस* (9%) और एच. गट्टुलाटस (14%). तोण्डी से वर्ष 2001 के दौरान संग्रहित छह जातियों के आकार रैंच क्रमशः 145-175 मि मी 145-165 मिमी, 105-190 मि मी, 110-165 मि मी, 140-190 मि मी और 150-190 मि मी थे. *एच.कुडा* की आहार नली में कोपीपोड्स (22.8%), माइसिड्स और कुमासीन्स (22.12%) सहित कवच प्राणियाँ (88.85%), ऑफीपोड्स और आइसोपोड्स (20.86%), डेकापोड डिम्भक और छोटे करीडियन चिंगट (20.67) पायी गयी. अंड का व्यास 0.5-0.8 मि मी के रैंच में था और माध्य जननक्षमता मादा समुद्री घोडे के शरीर भार का 56.8/ग्रा थी. लंबाई - भार संबंध तोण्डि से वर्ष 2001 के दौरान संग्रहित *एच. कुडा* के नर केलिए W=0.438615 ($L^{1.103592}$) और मादा केलिए W=0.370531 ($L^{1.231822}$) थे. प्रथम परिपक्वता की अवस्था में नर *एच.कुडा* और मादा *एच. कुडा* के आकार क्रमशः 66.07 मि मी और 77.99 मि मी थे. जून से सितंबर तक विस्तृत प्रमुख प्रजनन काल में जुलाई से अगस्त तक के श्रृंग काल के साथ तोण्डी में *एच.कुडा* का प्रजनन साल भर देखा गया. प्रजनन काल के दौरान की पकड में नर की अधिकता को छोडकर बाकी पकडों में नर लिंग अनुपात समान देखा गया. विभिन्न खाद्यों के प्रयोग करके किये गये *एच.कुडा* बच्चों के पालन से यह व्यक्त हुआ कि संपुष्ट आर्टिमीया नॉप्ली और समुद्री कॉपिपोड मिश्रित अच्छा खाद्य है, जिससे 60 दिनों की पालनावधि में 49.4 मि मी बढती और 0.316 ग्रा भार के साथ 56% अतिजीवितता प्राप्त हुई थी. 60 दिनों की पालनावधि में प्रति लीटर 3 समुद्री घोडे बच्चों की संभरण सघनता लंबाई और भार में उच्च वृद्धि (क्रमशः 43.67 मि मी और 0.313 ग्रा) तथा प्रति लीटर 1.51 के उच्च माध्य उत्पादन के साथ अनुकूलतम देखी गयी. 15 पी पी टी से 35 पी पी टी तक के लवणता रैंच *एच. कुडा* छोटों की बढ़ती केलिए स्वीकार्य देखा गया. 14 दिनों तक पालन करते समय 30 पी पी टी लवणता में उच्च माध्य अतिजीवितता (60.56), माध्य लंबाई (28.7 मि मी) और माध्य भार (39.1 मि ग्रा) प्राप्त हुए थे. पालन टैंकों के प्रकाशन से *एच.कुडा* बच्चों की अजिजीवितता में काफी प्रभाव होते हुए दिखाया पडा. आर्टीमिया नॉप्ली की अशन दक्षता बढ़ाने केलिए भागिक रूप से आवृत पालन टैंकों में 14 दिनों की अवधि में उच्च माध्य अतिजीवितता (71%) और क्रमशः 26.2 मि मी और 42.14 मि ग्रा के माध्य लंबाई और भार दर्ज किया. *एच.कुडा* के बच्चे लवणता , पी एच और फोरमालिन के चरम स्तरों का भी सहन करते हुए देखा गया. LC_{50} मूल्य निम्न पी एच केलिए 4.62, 4.83, 5.43 और 5.56 थे और 12,24,48 और 72h के उच्च पी एच केलिए क्रमशः 11.04 , 10.52, 10.33 और 10.23 थे. लवणता के मामले में निम्न लवणता केलिए 1.59,2.92,3.63 और 4.67 के LC_{50} मूल्य और 12,24,48 और 72 h केलिए LC_{50} मूल्य क्रमशः 58.08, 54.45, 51.29 और 49,26 थे. फोरमालिन का LC_{50} मूल्य 12,24,48 और 72 h केलिए क्रमशः 315,296.48,279.25 और 271.02 पी पी एम थे.

ABSTRACT

An organised fishery and trade of seahorses exist in the Palk Bay and Gulf of Mannar coasts of India. Six species of seahorses namely *Hippocampus borboniensis* Dumeril 1870, *Hippocampus spinosissimus* Weber 1913, *Hippocampus kuda* Bleeker 1852, *Hippocampus fuscus* Ruppell 1838, *Hippocampus trimaculatus* Leach 1814 and *Hippocampus guttulatus* Cuvier 1829 were identified from the southern coast, and the total landing at the major fishing centre, Thondi was estimated as 18.25 MT or 26,48,179 numbers of seahorses during 2001. The volume of seahorse trade from India was estimated as 9.75 MT of dried seahorses. A significant quantity of 1.6 MT (5,61,418 numbers) is also landed along the Quilon coast in Kerala, but it is not involved in any organised trade. *H. borboniensis* was found to be the major species (27.96%) at Thondi, followed by *H. spinosissimus* (22.14%), *H. kuda* (20.9%), *H. trimaculatus* (14%), *H. fuscus* (9%) and *H. guttulatus* (4%). The major size classes represented in the fishery were 145-175 mm, 145-165 mm, 105-190 mm, 110-165 mm, 140-190 mm and 150-190 mm respectively for the six species collected from Thondi in 2001. Crustaceans (88.85%), consisting of copepods (22.8%), mysids and cumaceans (22.12%), amphipods and isopods (20.86%), decapod larvae and tiny caridean shrimps (20.67%) dominated the gut contents of *H. kuda* at Thondi. Ova diameter ranged from 0.5-0.8 mm and the mean fecundity was 56.8 g^{-1} body weight of the female. The length-weight relationships were obtained as $W = 0.438615 (L^{1.103592})$ for males, and $W = 0.370531 (L^{1.231822})$ for females of *H. kuda* collected from Thondi. The size at first maturity for males and females of *H. kuda* was found to be 66.07 mm and 77.99 mm for males and females respectively. At Thondi *H. kuda* was found to breed year round, the major breeding season extending from June to September with peak from July to August. The sex ratio remained almost the same, except during the breeding season when more males were seen in the catches. The captive rearing of the hatchlings of *H. kuda* using different feeds showed that a diet of enriched *Artemia* nauplii and mixed marine copepods was the best combination, which gave mean survival rates of up to 56% and growth of 49.4 mm and 0.316 g after 60 days of rearing. A stocking density of 3 juveniles per litre was found to be the optimum, which gave high growth increment in length (43.67 mm) and weight (0.313 g) as well as the highest mean production per litre of 1.51 during a rearing period of 60 days. The juveniles of *H. kuda* were found to grow equally well in salinities ranging from 15 ‰ to 35 ‰. The highest mean survival (60.56%), mean length (28.7 mm) and mean weight (39.1 mg) were obtained at 30 ‰ while rearing for 14 days. Rearing tanks, which were partially covered to improve the feeding efficiency of *Artemia* naupIli registered the highest mean survival (91%) and mean length (36.2 mm) and weight (66.14 mg) of juveniles during a 14-day period. The juveniles of *H. kuda* were found to have reasonably high tolerance to extreme levels of salinity, pH and formalin. The LC_{50} values were 4.62, 4.83, 5.43 and 5.56 for low pH and 11.04,10.52,10.33 and 10.23 for high pH at 12, 24, 48 and 72 h respectively. In the case of salinity, LC_{50} values of 1.59, 2.92, 3.63 and 4.67 ‰ for low salinity, and 58.08, 54.45, 51.29 and 49.26 ‰ for high salinity were obtained for 12, 24, 48 and 72 h respectively. The LC_{50} for formalin was found to be 315, 296.48, 279.25 and 271.02 ppm for 12, 24, 48 and 72 h respectively.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

1. INTRODUCTION

1. INTRODUCTION

Seahorses are bony fishes (teleosts), belonging to the family Syngnathidae (fused jaws), which also includes pipefishes, pipe horses and sea dragons. They are among the most unusual fishes in existence, and their biology is as strange as the myths, which surround them. Seahorses are used primarily for medicine rather than food, and are sought in great numbers, for use in traditional medicines, as aquarium fishes, and as curiosities in many regions of the world. Indeed, it is this very popularity of seahorses for their varied uses, that make them vulnerable to overexploitation, and poses serious conservation concerns.

All seahorses belong to one genus *Hippocampus,* a name derived from the Greek words *hippos,* meaning horse and *campus,* meaning sea monster (Borror, 1960). The ancient Greek poets used the word *Hippocampus* as the name of a mythical creature half horse and half fish, on which the sea gods rode. And with such bizarre shapes with a horse like head, grasping tail, kangaroo like pouch for the young, independently moving eyes like a chameleon, and small fins emerging from slits in their bony armour, seahorses were treated as unique creatures by biologists, and historians as well.

There are about 32 species of seahorses all over the world (Lourie *et al.*,1999a). Although there are over 120 scientific names that have been cited, many of these are either misidentifications or have subsequently been inferred to be synonyms. (McAllister, 1990; Eschmeyer, 1998). The general shape of the seahorse is easily recognisable, but detailed species wise identification is difficult. Members of the same species may differ in appearance because seahorses can change colour and grow skin filaments to blend with their surroundings.

Seahorses are found worldwide, usually in shallow coastal, tropical and temperate seas. They are abundant in the Indo Pacific in waters less than about 20 m deep, but also in shallow rock pools, and depths of over 150 m from where they are trawled. Most seahorses are fully marine, although some species such as *H. capensis* live in estuaries (Whitfield, 1995). The feeding pattern of seahorses is peculiar in that their diet solely consists of live animals including small fish fry, crustaceans and other invertebrates. Seahorses are also unique in their reproductive behaviour, in which the males carry the eggs. This is one of the most extreme examples of paternal care yet known in the animal kingdom. The male fertilizes and broods the eggs, produced and deposited into its pouch by the female during courtship and mating, and in turn delivers the hatchling, after a long period of pregnancy and labour. Most species of seahorses studied so far show unique sexual fidelity and form faithful pair bonds (Lourie *et al.*,1999a), in which case one male and one female mate repeatedly and exclusively giving up opportunities to interact with non-partners. The newborn seahorses grossly resemble the adults, except differences in body proportions and they soon start active feeding.

Seahorses form one of the most important fishery resources of the seas. Though small in size, these fish account for a well established trade both in the domestic and international markets, finding their use in the Traditional Chinese Medicines (TCM), and curios in the dry form, and as favourite ornamental fish in the live form. Seahorses have been used in TCM for perhaps 600 years (Vincent, 1996). They have wide medicinal use for the treatment of a variety of ailments including asthma, arteriosclerosis, impotence, incontinence, thyroid disorders, broken bones, skin ailments and heart diseases. Medicine and food are closely interrelated in Chinese culture, and large number of seahorses are eaten as tonic foods, even without prescription. However, perhaps about 30% of seahorses sold in China are now used in patent medicines too (Lourie *et al.*,1999a).

Although, seahorses are considered to be delicate and difficult-to-keep fishes in the aquarium, they are among the most popular ornamental fishes. Since the captive maturation and larval rearing of seahorses pose great difficulties, most of the captive aquarium seahorses are wild-caught, a majority of them coming from Indonesia or the Philippines, and exported to North America, Europe and Japan. These fishes are also widely used in curios like jewellery, paperweights, key chains etc., owing to their extraordinary shape, the ease with which they dry, and their series of external bony plates that enable them to retain shape even after death.

Seahorses are often caught incidentally as by-catch in trawls and seines, but many are also targeted by some of the world's poorest fishers, along with chanks and other gastropods, sea cucumbers etc., using small nets or by hand collection. Seahorse fisheries are individually small, but collectively very large and potentially damaging to wild populations. Seahorse fishing has now become an important source of income for subsistence fisheries in many developing countries. Their reliance on seahorse is increasing in response to the twin pressures of growing demand, and declining resources because of overexploitation and destructive fishing techniques. Seahorses are particularly prone to overexploitation because of their behaviour and ecology (Lourie *et al.*, 1999a). Their lengthy parental care and male pregnancy combined with small brood size, limit reproductive rate, and the young are also removed from the wild when the father is caught. Seahorses form faithful pair bonds for reproduction and are sparsely distributed with limited mobility in their habitat. Fishing easily disrupts their social structure, and the lost partners are not quickly replaced. Fishing exerts a substantial new selective pressure, since the natural adult mortality rates are typically low, as shown by Vincent and Sadler (1995). Moreover, seahorses live in the coastal zone such as sea grass, mangrove, coral and estuarine habitats which are subjected to frequent degradation and destruction by human interference.

Such inherent vulnerabilities rendered the seahorse populations all over the world, risky of overexploitation. Owing to their varied economic uses, the demand for seahorses in the global market is increasing year by year, and they are heavily exploited. The world trade of dried seahorses was estimated to be over 20 million numbers, a great majority of them for use in TCM (Vincent, 1996). Several hundred thousand more seahorses are exported live each year for home and public aquaria especially in the North American and European markets, and a similar number are sold each year dried as souvenirs and curiosities. The global trade on seahorses is not well documented and mostly take place in unorthodox means like carriage in passenger baggage, undeclared parcels etc. The trade has been expanding globally at a fast pace and the demand always exceeded supply. The retail prices of seahorses are very high, and the steep cost itself sometimes enhancing their value in purchaser's eyes (Lourie *et al.*, 1999a).

This exorbitant demand has exerted considerable fishing pressure on the seahorse resources, in at least 45 countries, and Special Administrative Regions that trade in seahorses. Many of the species described currently have already been placed under the list of endangered animals, and this poses serious conservation issues regarding the existence of seahorse populations in the world seas. Hence of late, the global research on seahorses is more oriented towards conservation and management strategies of the fragile seahorse populations around the world. Aquaculture of seahorses is thus an important option for conservation, in view of the drastic decline of world seahorse populations. Aquaculture could contribute to conservation efforts by producing healthy young of most of the economically important species of seahorses, which would help to ease the fishing pressure on the wild populations.

However, there are still many more gaps in the scientific investigation on seahorses, than that in the case of most of the other economically important group of marine animals like crustaceans, and other fishes. The basic issue of taxonomy itself has not been fully attended to. Lourie *et al.* (1999a) shortened a majority among the 120 species descriptions that existed till recently to about 32 species, based on a worldwide survey. However, this according to her own description is only tentative, and many more species are still doubtful, and further research is recommended. Apart from these, many aspects of the biology and fisheries of seahorses are still to be described fully, since there is no organised fishery for seahorse in most parts of the world. The general aspects of behaviour, feeding pattern, growth, reproductive characteristics, larval development etc. have been validated only for a few individual species. Their restricted distribution and scanty availability, coupled with difficulties in regular sampling make such collection of data extremely difficult. Moreover, the trade routes are highly non-regularised and the data collected from fisheries and traders is unreliable in most cases.

India has a long history of trade on seahorses, which mostly originate in the Southeastern coast, particularly Tamil Nadu. Limited quantities of seahorses are also reported to be collected from the coasts of Kerala, Maharashtra and Karnataka. There exists a well-established seahorse trade along the south Tamil Nadu coast, especially the Palk bay and Gulf of Mannar areas as an alternate fishery, in view of the dwindling resources of sea cucumber along these coasts (Marichamy *et al.*, 1993). In fact there is a target fishery existing along the Palk bay coast whereas the landings mostly come as trawl by-catch in the Gulf of Mannar region and Kerala coast. Most of the catch is dried and exported to Singapore, Hong Kong and Malaysia, apart from their local consumption in limited quantities in folk medicine for treatment of asthma, fits etc. Vincent (1996) reported the trade volume to be about 3.6 – 6.0 tons of dried seahorses per annum for export from India. According to official estimates (MPEDA, 2003), about 2.53 tons of seahorses worth Rs. 15 lakh were exported from India during 2000-01, mainly to Singapore, UAE and Hong Kong. This has increased to 4.5 tons during 2001-02, worth Rs. 27 lakh, Chennai being the major port of activity. Obviously, the UAE is only a transit point, and most of the Indian export is destined to Singapore or Hong Kong, countries with a sizeable population of ethnic Chinese communities.

Despite the existence of a flourishing trade the study of Indian seahorses attracted little interest till recently. It was suggested (Lourie, pers. communication) that there are at least 5 species of seahorses, viz. *H. kuda, H. spinosissimus, H. fuscus, H. trimaculatus,* and *H. kelloggi* in the Indian waters. However, the *H. kuda* complex might contain several other species, which were difficult to be identified, and the number of species might still be more. Apart form this tentative assessment, there has not been a serious study thus far, on the seahorse populations of the Indian seas. The number of species available, their biology, suitability to aquaculture and larval rearing have yet not been studied. Moreover, there are enough indications that the seahorse population in our seas are fast declining year by year which is reflected in the gross reduction in catch in terms of volume, and the mean size of the individuals caught (Vincent, 1996). Thus considerable efforts also need to be invested on conservation aspects of the dwindling seahorse fishery. The greatest quantity of the trade originates from the Tamil Nadu coast, especially the Palk Bay and Gulf of Mannar areas, and the Kerala coast, and therefore the present study investigates the features of the seahorse fishery along these areas.

The major objective of the present study is to investigate the taxonomy of seahorses, *Hippocampus* spp. along the southern coast of India, based on morphological features, and to outline the biological characteristics of *H. kuda,* which is one of the dominant species encountered. Captive rearing studies were also conducted to evaluate the conditions suitable for captive breeding, the best feed combinations for the hatchlings, the optimum water quality parameters for juvenile rearing, and the tolerance of juveniles to some of these parameters and chemotherapeutants.

2. REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Seahorses, with their distinctive appearance and aesthetic appeal, have been the object of fascination and myth for centuries. Their unique behaviour and perceived medicinal properties have enabled them for being widely used as cure for a wide range of dreaded maladies, apart from their use as preferred aquarium fish and dried curios. Besides their intrinsic worth, these fishes are unusual and valuable in behavioural, anatomical, ecological and economic terms. They exhibit the most highly specialised paternal care and show rare sexual fidelity to only one partner. They are voracious predators with neither teeth nor stomach, and have unusual grape-like gills. They contribute significantly to the nutrient dynamics in sea grass communities, provide income for many subsistence-fishing families, and command very high prices.

Ironically, it is their very popularity that places seahorses in danger. They are sought in great numbers for their varied uses. Recent population declines in many regions of the world raise concerns about the persistence of seahorse in the wild. Habitat damage may also threaten seahorses apart from fishery exploitation. Seahorses can serve as potent symbols for their very important, but very degraded sea grass, mangrove, coral and estuarine habitats.

Conservation assessment and management of seahorse populations is restricted by our lack of knowledge of their biology in the wild. Abundance, geographic range, behaviour, ecology and reproductive capacity of most species and populations remain unstudied. Even the total number of seahorse species is uncertain. Taxonomic confusion hinders communication and can make comparisons across research studies unreliable. Lack of standardisation also precludes accurate assessments of total population size and geographic range for a species, thus hampering conservation assessments. Even where an assessment is possible, naming uncertainties make it difficult to apply conservation measures, undertake trade research and develop protective legislation.

The lack of works on seahorse biology means that it is necessary to extrapolate from a few studies on single species to the genus in general. Vincent (1996), based on extensive research worldwide, has observed that there are general patterns of seahorse biology, and proposed the view that seahorse behaviour and ecology is rather similar across species. Studies on pipefish biology have also helped to understand seahorse biology, where characteristics are shared by the whole family.

Therefore, the present review compiles all the currently known, although often very limited, information on the distribution, taxonomy, life history and biology of the world's seahorse species. Emphasis is also given to the ever-expanding trade on seahorses and the strategies to address the consequent issues of conservation and management of the wild populations.

2.1. Taxonomy and classification

Seahorses comprise one genus, *Hippocampus*, of the family Syngnathidae, which otherwise consists of about 35 genera of pipefishes, pipehorses and sea dragons, within the order Gasterosteiformes. Seahorses are believed to have evolved at least 40 million years ago (Fritzsche, 1980). Classification of seahorse species has been problematic for many years. Much confusion surrounds seahorse species names in the literature, including field guides, scientific publications and conservation documents, as well as museum collections, and in the wider scientific community (Lourie *et al.*, 1999a). More than 120 species names had been proposed for seahorses over the past centuries. However, many of these turned out to be synonyms for the same species, or misidentifications (McAllister, 1990; Eschmeyer, 1998). Seahorses can change colour and grow skin filaments to blend with their surroundings, so that members of the same species can differ in appearance. Also, the individual variations in shape, size and form or the influence of habitat, geographic locality, temperature, and / or age, have not been fully explained. Pipefishes, pipehorses and seahorses comprise a distinct part of an apparent evolutionary gradient (Vincent, 1996); pipefishes are long, straight fishes and have tail fins; pipehorses have heads bent at about 30 degrees to the straight body and have developed slightly grasping tails; whereas seahorses have heads at right angles to the trunk, and have fully prehensile tails.

An entry in the Linnaeus' *Systema Naturae* (1758) marked the beginning of formal seahorse taxonomy. Linnaeus (1758) could recognise only a single species and named it *Syngnathus hippocampus*. However, *Syngnathus* is now recognised as a pipefish genus. New species had since been described by over 30 authors including Kaup, Gunther, Steindachner, Temminck, Ruppel, Dumeril, Whitley, Fowler, Jordan, Castelnau, Cantor, Lesson and Girard, the majority of which were published in the 19^{th} century (Pietsch and Anderson, 1997). Bleeker wrote about 520 ichthyological papers and described over 1100 new fish species (Boeseman, 1973; Harting, 1973), including eight seahorse species.

Kaup (1856), Gunther (1870) and Dumeril (1870) made initial attempts to rationalise seahorse taxonomy, while preparing catalogues for the European museums. Ginsburg (1937) published a revision of the syngnathids of the Eastern Pacific including fossils as well as species. Vari (1982), Paxton *et al.* (1989) and Gomon (1997) noted that a comprehensive revision of seahorse taxonomy was urgently needed. Vari (1982) revised the Western Atlantic seahorses and reduced the plethora of names. Dawson (1985) published a comprehensive book on the Indo Pacific pipefishes, but did not describe seahorse taxonomy.

These revisions were mostly incomplete and have resulted in much duplication and synonymy, because of many reasons. Each revision was based on a limited geographical area, and the knowledge of variation in the genus as a whole was lacking. In most cases, the original species descriptions were often inadequate and original type specimens not particularly examined. Vincent (1996) made extensive surveys of the population worldwide and proposed four broad groupings of the exploited species of seahorses that can be recognized, as follows:

a) *H. kuda* complex species that are medium sized, slender and smooth seahorses with fine coronets;

b) *H. histrix* complex species that are medium sized, spiny seahorses with fine coronets;

c) *H. kelloggi* complex seahorses that are larger, solid looking, and smooth seahorses with thick coronets; and *d)* *H. trimaculatus* complex species, those are smaller, deep-bodied and smooth seahorses with no coronet and characterised by three spots on the dorsal part of the upper trunk.

Size is an imprecise indicator of species grouping, both because young of large species can be confused with adults of small species, and because adult sizes of many fishes, and apparently seahorses, decline under fishing pressure (Vincent, 1996). The biology of most species generally does appear similar, and most species are vulnerable to exploitation. Taxonomic studies cannot also be based on the common names of seahorses prevalent in many parts of the world, as they have not yet been standardised.

Lourie *et al.* (1999 a) tried to overcome most of the inherent limitations in seahorse taxonomy by attempting a comprehensive revision of species hitherto described by comparing the available species from a wide geographical range, with the type specimens kept in museums. They also relied on genetic data to establish the species. According to Lourie *et al.* (1999a), the entire list of seahorse species could be shortened to just 32 species, as most of the broad groups of related species were identical, based on morphometric and genetic work. However, some of these may still be complexes, containing more than one discrete species, and it required further research. Lourie *et al.* (1999a) identified seven species of seahorses, which are heavily exploited in Vietnam, using morphometric and DNA sequence data.

2.2. Distribution

Seahorses are found worldwide, usually in shallow, coastal tropical and temperate waters, the greatest abundance of them being in the Indo-Pacific. Most seahorse species are fully marine, except some such as *H. capensis*, the Knysna seahorse, which live in estuaries where they experience fluctuating salinities and suffer mortality during freshwater influx (Whitfield, 1995). There is no reliable evidence of freshwater seahorses, apart from the report of Roule (1916) on the occurrence of seahorses from the Mekong River 300km upstream of some waterfalls, which was however, based on third-hand information and highly unlikely to be correct.

2.3. Habitats

Syngnathids (seahorses, pipefishes, pipehorses and sea dragons) are the dominant family of fishes across a wide range of sea grass habitats in diverse geographic areas around the world (Pollard, 1984) and are important predators on benthic organisms (Tipton and Bell, 1988). Their range extends roughly from 45^0north to 45^0 south, with more species occurring in the West Atlantic or the Indo-Pacific region (Vincent, 1996). Seahorses primarily occupy inshore habitats in narrow strips along the coast in less than about 20m deep, but have also been encountered in shallow rock pools and trawled from depths of over 150m. Many species like *H. whitei, H. borboniensis, H. erectus, H. guttulatus* and *H. zosterae* live among sea grass or eel grasses in temperate and tropical regions, while others like *H. kuda* occur in flooded mangrove forests. Seahorses like *H. subelongatus* also live in soft-bottom areas where sponges and sea squirts are abundant. Species like *H. comes* and *H. zebra* are found among corals in the tropics. Some species need very specific habitats, like *H. bargibanti,* which has so far only been found on two species of sea fans (Lourie *et al.,* 1999a).

2.4. Biology

2.4.1. Behaviour and Ecology

2.4.1.1. Morphology

All seahorses have the same basic body shape: a horse-like head perched at right angles to an erect body which is devoid of scales, a long tubular snout which sucks food, eyes which swivel independently in search of food, the skin stretched over a series of bony plates visible as obvious rings around the trunk, and a prehensile tail usually grasping a hold fast (Vincent, 1996). Seahorses have lost pelvic and caudal fins, retaining only one propulsive dorsal fin, two small ear-like pectoral fins used for stabilization and steering, and a tiny anal fin. The eye structure is characterised by a few rods, many cones and a fovea, making them adapted to diurnal vision (Engstrom, 1963).

2.4.1.2. Mobility

Seahorses are relatively sedate swimmers, adapted for manoeuvrability in their complex habitat rather than for speed (Blake, 1976). Only the dorsal fin provides propulsion, while the ear-like pectoral fins below the gill opening are used for stability and steering; the function of the little anal fin is unknown. The seahorse uses its unique, muscular, prehensile tail as an anchor, wrapping it around sea grass stems, coral heads or any suitable object. When threatened, a seahorse's defence reaction is to tuck its head close to its body and tighten its tail-hold.

Both sexes of seahorses also use their tail to grasp a partner in mating and greeting rituals (Vincent and Sadler, 1995) although only males wrestles with their tails to gain access to mates (Vincent, 1994a). The seahorses lack a tail fin, which is the main power source for most fish, and their bony armour makes it difficult to flex the body. Seahorses, therefore, tend not to move much, relying more on camouflage to avoid detection by predators then on speed for escape. They are however, capable of swimming swiftly over a short distance, usually with their tail trailing behind them.

2.4.1.3. Activity and spatial distribution

Seahorses are generally more active during day light hours (diurnal) than at night (nocturnal). *H. whitei* in Australia is reported to become active around dawn as the seahorse pairs initiate their greeting ritual (Vincent and Sadler, 1995). In contrast, *H. comes* in the Philippines is unusual in being nocturnal, as they retreat into crevices in the coral at dawn, and are not seen again during daylight hours (Perante *et al.*, 2002).

Seahorses are better suited to manoeuvrability than speed. Seahorses will probably be slow to recolonise areas from which they have been removed (Vincent, 1996). However, they show great site-fidelity, at least during the breeding season. Males of most species apparently move less than females, perhaps because they are heavily laden with embryos (Lourie *et al.* 1999a).

Seahorse population density tends to be low. *H. whitei* in Sydney occurred at densities of about one per $6m^2$ of preferred mixed sea grass, mostly *Posidonia* and *Zostera* habitat (Lourie *et al.* 1999a). Though this is typical of many seahorse species, densities as high as 10 to 15 seahorses per m^2 have also been reported in sea grass habitats in India (Vincent, 1996).

The field study on the temperate Australian seahorse, *H. whitei* showed that males often have a home range of only $1m^2$ (even holding on to the same sea grass shoot for weeks), and females have a maximum home range of about $100m^2$ (Vincent and Sadler, 1995). Each female's home range is centred on that of her mate, and her greater home range will reduce feeding competition within the pair. Seahorses have yet not been reported as competing overtly for space in the wild.

Adults may disperse during the short-range seasonal migrations that are thought to occur in some populations, but most movement to new areas probably happens when adults are cast adrift by storms or carried away while grasping floating debris (Vincent, 1996). Young seahorses are more likely to colonize new or depleted areas, because they are often carried away from natural habitats despite attempts to settle on to the substrate (Vincent, 1996). The extent of dispersal by this mechanism is unknown, but it offers some possibility of gene flow among the populations. However, this observation by Vincent (1996) that in the wild, the young moves into substrate contradicts the observations in aquaria of newborn seahorses rising straight to the surface to gulp air to fill their swim bladders (Schiotz, 1972).

2.4.1.4. Camouflage

Seahorses are masters of camouflage, and thus commonly very difficult to be spotted in the wild. Many species have blotchy skin patterns, which help obscure their outline. They can remain virtually immobile and can change colour in a matter of minutes to match their surroundings. Most seahorses are neutral colours from beige to brown to black. One individual even turned fluorescent orange to blend with a piece of flagging tape used to mark out a scientific plot (Lourie et al.,1999a). In addition, seahorses can grow extra skin filaments (Ginsburg, 1937) to imitate algal fronds attached to sea grass stems, or the seaweed of their habitats. Encrusting organisms like bryozoans, algae and hydroids settle on their skin camouflaging them further (Rauther, 1925). Certain species appear to have a greater propensity to grow skin filaments or host encrusting organisms, but this may merely be an environmental effect, as indicated in the case of *H. Zosterae* brought into an aquarium tended to lose their skin filaments within a few days (Lourie *et al.*,1999a).

The ability of seahorses to be cryptic probably facilitates both prey capture and escape from predators. Their tremendous flexibility in appearance means that colour and skin filaments are usually poor criteria for species identification in seahorses, which may partly explain why seahorses have been so little studied. Nonetheless, some markings and patterns and thicker filaments can be useful as supplementary diagnostic characters to support identification.

2.4.1.5. Communication

Seahorses are believed to communicate among one another by way of the sound they make, as well as the body colour changes. Seahorses are capable of making noises, mainly small clicks, by moving two parts of their skull against each other (Colson *et al.*, 1998). These are clearly audible, both from seahorses foraging in the water and from seahorses held out of the water. No hydrophone work has yet clarified the purpose of these clicks. Reports of more intense clicking during courtship (Fish, 1953) have not been substantiated by limited hydrophone work to-date (Lourie *et al.*, 1999a).

Colour change serves as another mode of communication among seahorses. They commonly brighten quickly (within seconds) when involved in social interactions apparently signalling interest and / or recognition, but perhaps also indicate health and vitality. Either sex may brighten first during morning greetings by *H. whitei* pairs (Vincent and Sadler, 1995).

2.4.1.6. Feeding

Seahorses are voracious predators, relying entirely on live moving food. Camouflage helps seahorses in being ambush predators. They will ingest anything that fits into the mouth, mostly small crustaceans, but also small fishes, ambushing the prey by inhaling rapidly through their snout (Vincent, 1996). Seahorses are thought to eat enough to affect the structure of benthic invertebrate communities (Tipton and Bell, 1988). It appears that seahorses are able to obtain prey equally well over a wide range of habitat complexity, although they prefer to grasp a hold fast when feeding (James and Heck, 1994).

Seahorses have no teeth and no stomach (Rauther, 1925). Prey are swallowed whole and pass rapidly through the digestive system. Young seahorses alter diet as they grow (Boisseau, 1967a; Do Huu Hoang *et al.*, 1998), perhaps as they change microhabitats or as feeding skill develops. Among their pipefish relatives, pregnant males eat more plankton than other pipefishes, perhaps because they are too slow to chase larger prey (Svensson, 1988), and this is also likely to be true for seahorses.

The seahorses in aquaria require large volume of food. Two week old seahorses are reported to eat at least 3600 baby brine shrimp in a ten-hour period (Herald and Rakowicz, 1951). Tipton and Bell (1988) observed that *H. zosterae* ate enough copepods in a Florida sea grass bed to control population of at least one of these crustacean species. This was further emphasised by Liang (1992) who reported that pelagic copepods are indispensable for rearing seahorse fry. Lu *et al.* (2002) determined the daily food consumption rate of *H. kuda* as 1177.25 cal per individual, and the evacuation rate as 0.1444 g per 100 g per hour, in China. The food and energy conversion efficiency were 20.04 % and 31.42 % respectively.

2.4.1.7. Growth

Growth rates have not been investigated in any detail, but young seahorses are known to exhibit growth inflection points (where rates of growth change) as they switch between prey types (Boisseau, 1967a; Vincent, 1996). Adults grow more slowly as they grow larger (Vincent and Sadler,1995).

Strawn (1958) who outlined the life history of the Pigmy seahorse *H. zosterae* at the Cedar Key in Florida reported the growth rate of young seahorses to be temperature dependent. New born young in two broods of Cedar Key *H. zosterae* ranged from 7 to 9 mm, which in aquarium grew to as long as 18 mm during a 17 days period, and fed with newly hatched brine shrimp. He observed slow average growth rates of the over wintering fish, and rapid growth rate at high temperatures. Strawn (1958) suggested that during most of the year, the long breeding season coupled with the production of at least three generations a year make the determination of the growth rates of wild Cedar Key sea horses difficult. Vincent (1996) reported that skilled aquaculture could produce *H. kuda* type sea horses measuring 16 cm in just six months. Accurate determination of seahorse age and growth rates in the wild awaits analysis of seahorse otoliths.

Natural life span and mortality rates for sea horses - and the parameters that define them – are virtually unknown, and in need of research, because longer lived or slower-growing fish species tend to be more vulnerable to over-exploitation (Anon, 1990 a). Life span is only about 1-1.5 years in the very small species *H. zosterae* (Strawn, 1958), but has been inferred from size distributions and captive observations, to be about 4-5 years for most medium sized Indo-Pacific species (Vincent, 1996). Strawn (1958) assumed that the pygmy sea horses that did not over winter survived hardly a year, unlike the over wintering fish, which lived longer.

2.4.1.8. Predation and Mortality

Mortality is probably the highest in young seahorses (Vincent, 1996), which are highly vulnerable to piscivorous fish. Few predators appear to target adult seahorses, perhaps because their camouflage and immobility make them difficult to be detected and because their bony plates and spines make them an unpalatable meal (Lourie *et al.*, 1999a). They are however taken by crabs, large pelagic fish and humans (Whitley and Allan, 1958). Jordan and Gilbert (1882) reported a large seahorse (which they named as *H. stylifer)* taken from a redsnapper stomach, and also some seahorses from the gut contents of eldorado (dolphin fish) in the Caribbean. Longley and Hildebrand (1941) mentioned 20 specimens of seahorses (which they denoted as *H. punctulatus* Guichenot*)* taken from the stomach of a Remora. Largely undigested seahorses have also been found in the stomach contents of yellow fin tuna from Hawaii (Herald, 1949). The pygmy seahorse *H. zosterae* maintains a relatively stable non-breeding population during the winter when many of the possible predators are scarce or absent from the shallow water of the grass flats (Strawn, 1958). One of these predators, the blue crab *Callinectes sapidus,* is extremely abundant on the flats in the summer and it frequently captures and devours the seahorses and pipe fishes (Strawn, 1958). Other animals which eat seahorses include flat heads (*Platycephalus* sp.*)* which are known to have eaten *H. breviceps* and the striped Angler fish (*Antennarius striatus)* which eat *H. abdominalis* (Lourie *et al.*, 1999a).

Natural adult mortality rates in seahorses are likely to be low, as reported by Vincent and Sadler (1995) based on tagging studies of *H. whitei.* Fisheries Management tends to invoke the general rule of thumb that fishing mortality should be lower than natural mortality (Anon, 1990 a). It means that if natural death rates are low among adult seahorses, then heavy fishing will place unusual pressure on these populations. Young seahorses disperse and do not obviously compete for any resources, suggesting that survival may not be affected by density. This would mean that declining seahorse numbers, and hence declining numbers of young, would not necessarily lead to increased juvenile survival (Vincent, 1996).

2.5. Reproductive Biology

The most characteristic feature distinguishing seahorses from other fishes is their mode of reproduction. It is the male fish that get pregnant, giving birth to the young ones. The eggs are carried by the male in a well-developed brood pouch, and there is a placenta through which the embryo receives some nutriment. This is said to be the most extreme example of male parental care yet discovered.

The large yolky eggs are deposited by the female through the prehensile ovipositor into the male's brood pouch during courtship and mating. Thus earlier reports on seahorse reproduction suggested that there was apparently a complete sex role-reversal, and the females being bigger and thought to be more active play the leading role at Courtship. However, recent observations indicate that there is no apparent reversal of sex roles and it is not an outright violation of Nature's law, since the eggs are still produced by the females and sperms by the males, and the latter compete more to get pregnant than the females do, to transfer the eggs, thus not defying the basic definition of the two sexes.

2.5.1. Life history parameters

2.5.1.1. Age at first maturity

Basic life history parameters like age at first maturity and brood size are unknown for many seahorse species. Seahorses of the small species like *H. zosterae* mature at two to three months when they reach about 16-18mm size (Strawn, 1958), while those of many other species like *H. abdominalis, H. comes, H. erectus, H. fuscus, H. guttulatus, H. hippocampus* and *H. whitei appear* to be mature at six months to one year (Lourie *et al.*, 1999a). Sexual maturity in male can be recognised by the presence of a brood pouch, although its size will vary with reproductive state. Females mature at much the same size as males, but physical manifestation is less obvious.

Sexual maturity is also dependent on temperature. Strawn (1958) observed that the male pygmy seahorse *H. zosterae* born in the cold water of later winter and early spring evidently took about three months and 20 mm length to mature. The rapid growth rate observed at higher temperatures suggested the attainment of breeding size during warm weather in less than three months and a length of 16 mm. This was confirmed by captivity studies, where the seahorses reared in aquaria during the summer season, had fully developed brood pouches at the age of two months (Strawn, 1958).

2.5.1.2. Breeding season

The length and timing of the reproductive season of seahorses varies with location and will be influenced by light, temperature and turbulence from monsoon rains and high winds (Vincent, 1996). Detailed studies have yet not been done to ascertain the breeding season of most of the seahorse species. The breeding season of *H. zosterae* appears to correlate closely with seasonal changes in the length of the day (Strawn, 1958), which was inferred from the proportion of mature males, which had young in the brood pouch during different seasons. Strawn (1958) reported that during the period between the vernal and the autumnal equinox, about two-thirds of the mature male *H. zosterae* had young in the pouch, while in the 36 days following the autumnal equinox, and the 30 days preceding the vernal equinox, only less than one-fourth had young.

Although temperature was not found to correlate closely with the beginning and end of the breeding season in the case of *H. zosterae* (Strawn, 1958) it might be important as a wide limit. Salinity, however, appeared to have had little effect on the breeding season of *H. zosterae* (Strawn, 1958).

Seasonal pattern in seahorse behaviour are apparent in temperate species such as *H. whitei* (Australia), which has a distinct breeding season, usually lasting about six months in the summer (Vincent and Sadler, 1995; Boisseau, 1967a). They disappear from their inshore breeding grounds during the winter and are believed to spend time in deeper waters. Reproduction in tropical species, in contrast, is commonly influenced by rainy seasons. For instance *H. fuscus* breeds at different times of the year on the east and west coasts of Sri Lanka, according to the timing of the monsoons (Lourie *et al.*, 1999a), although *H. comes* in the Philippines appears to breed all year round regardless of rains (Perante *et al.*, 2002).

2.5.1.3. Sexual Dimorphism and Sex ratio

The sex of mature seahorses could be determined by the presence or absence of a brood pouch. At the age of first maturity, the brood pouch of male specimens of *H. zosterae* was represented ventrally on the first few caudal segments by an elevated ridge surrounding the area of the future pouch (Strawn, 1958). During the breeding season mature males with young are generally found in the population. Other indications of breeding are a flabby pouch on males without young, and females with full bodies and large eggs in the ovaries. A courting male pumps his pouch full of water until it looks like a balloon ready to burst. In contrast, the pouch of a male out of breeding season is a shrivelled structure that requires modification before it can be distended (Strawn, 1958).

Most seahorse species are also slightly sexually dimorphic in features other than the brood pouch. Male seahorses are often conspicuous, colourful, vocal and aggressive than females. These sex differences perhaps arise from competition among males to defeat rivals and attract mates (Vincent, 1994). Males of many species have tails that are proportionally longer than the trunks (Lourie *et al.,* 1999a), perhaps because they carry the brood pouch on their tail and/or because they wrestle with their tails in courtship. They also have proportionately shorter and thicker snouts than females in at least *H. abdominalis, H. fuscus and H. zosterae*. Male *H. abdominalis* differ from the female in weight and markings, being rather heavier and more blotchy on average (Lourie *et al.,* 1999a).

Seahorse populations commonly have an equal number of male and female adults (Vincent, 1996). However, there is no idea about the sex ratios at birth. Also there is no information available about how sex is determined in seahorses, whether genetically or environmentally. Strawn (1958) found that the females outnumbered males in the collection of *H. zosterae* throughout a 12 months period at Cedar Key, Florida. He obtained a similar male to female ratio of three to seven, as that reported by Gudger (1906) for the pipefish *Syngnathus floridae* Jordan and Gilbert, at Beaufort, North Carolina. The sex ratio of seahorses obtained can also be influenced by the season, and the collecting site, probably correlated with the types of environmental vegetation (Strawn, 1958).

2.5.1.4. Fecundity and brood size

Seahorse fecundity (per spawning per annum) in orders of magnitude is lower than that of most fishes taken by large-scale fisheries. Males of most species produce about 100-200 young per pregnancy, although smaller species such as *H. zosterae* may release about five offspring (Vincent, 1990). However, Strawn (1958) reported that the largest batch of eggs found in the ovaries of a female of 34 mm size was 69, and the most young taken from the pouch of a male of 31 mm were 55. The numbers of eggs though similar were rarely evenly divided between the two ovaries. Large eggs were of similar size except for an occasional undersized one which would produce a non-viable runt in the pouch of the male and were easily counted, while small eggs were variable in size and were difficult to count. Fully mature eggs were rounded and tended to be loose in the ovary, while less mature eggs were tightly packed and angular. Strawn (1958) suggested that the female *H. zosterae* evidently dumps the whole contents of the ovary into the pouch of the male, and in some cases this included what appeared to be all the large eggs in the ovary still tightly joined together, angular in shape, and covered by maternal membranes. Thus, based on available evidence that the young in almost all the males examined appeared to be of the same age, and from the general similarity in numbers of eggs in the females and males. Strawn (1958) concluded that one female usually furnishes all the eggs found in the pouch of male.

The maximum known brood size for seahorses is reported to be 1572 young produced by one *H. reidi* male (Vincent, 1990). The brood size of the tiny species *H. bargibanti* is much smaller, about one or two embryos (Lourie *et al.*, 1999a).

Strawn (1958) reported that the broods of *H. zosterae* male at Cedar Key, Florida were about 15 days, and a male produced two broods per month. *H. whitei* seahorses near Sydney, Australia, experience about seven consecutive, 21-day pregnancies per year, amounting to a total production of 1000 young per pair, per annum (Vincent and Sadler, 1995).

2.5.1.5. Gametes (Eggs and sperm)

Male seahorses provide the most extreme example of parental care yet known, for only the male becomes pregnant. It is still the female, however, that produces large, energy rich, immobile eggs and the male that produces smaller energy poor, mobile sperms. Therefore, males are entirely male, despite brooding the young.

Seahorse eggs are large, pear shaped and few in number, compared to those of most bony fishes. The eggs typically contain oil droplets and are red or orange in colour (Hardy Jr., 1978), presumably because of carotenoids that function in providing intracellular oxygen. Eggs develop along a spiralling assembly line in each of the two ovaries, to be shed from both ovaries simultaneously when ripe. During the reproductive season, eggs at all stages of development are present; the earlier stage in the centre of the ovaries and the later stages with yolk (post-vitellogenic) towards the outside of the spiral (Boisseau, 1967 a).

The eggs are hydrated shortly before copulation. All hydrated eggs are transferred to the male during mating, while unhydrated oocytes continue to mature, and getting ready for the next mating (Boisseau, 1967 a). Reproductive synchrony between sexes is important since the female seahorse appears unable to store hydrated eggs for long, commonly dumping them if she has not found a mate within about 24 hours of hydrating eggs (Vincent, 1994 b).

Sperm development is underway throughout the year, but the sperms themselves are only present in the breeding season, stimulated by courtship. Compared to other teleosts, seahorse sperms are less numerous and remain the testes for only a short time (Boisseau, 1967 a).

2.5.1.6. Pair bonds and greetings

Seahorses provide the only known example of monogamy in fishes living in sea grasses or mangroves. Seahorses of most species studied thus far, form sexually faithful pair bonds that endure through multiple mating, and perhaps multiple breeding seasons, as evidenced by *H. whitei* (Vincent and Sadler, 1995), *H. fuscus* (Vincent, 1995a), *H. zosterae* (Lourie *et al.*, 1999a), *H. comes* (Perante *et al.*, 2002) and *H. reidi* (Dauwe and Nijhoff, 2001). One male and one female mate repeatedly and exclusively eschewing opportunities to interact with non-partners, which was confirmed by extensive observations in the case of *H. whitei, H. comes* and *H. reidie* in the wild population.

H. whitei in Australia is the most thoroughly studied of the seahorses, with all members of a population individually monitored (Vincent and Sadler, 1995). In most of such monogamous seahorse species, pair bonds appear to be reinforced by daily greeting rituals between partners, that continues throughout the male pregnancy. For instance, male and female *H. whitei* come together early each morning, the female swimming towards the male and dance for 6-10 minutes, performing the first few moments of courtship. They change colour twirling around a common hold fast, and promenade together across the seabed, with linked tails. The female finally leaves the male and the pair remains apart for the rest of the day. The females determine the timing and duration of greeting, but males control the action by leading in promenades and circling. It is the one social interlude in an otherwise solitary day (Vincent and Sadler, 1995).

Greeting rituals appear to facilitate reproductive synchrony of male and female so that the female has ripe eggs ready as soon as the male gives birth, with the pair commonly remating later that same day (Vincent and Sadler, 1995).

They also apparently serve to reinforce pair bonds (Vincent, 1995a), and probably cue a female to her mate's impending delivery enabling her prompt preparation of a new clutch of eggs (Vincent, 1994b). Both sexes refuse to respond to displays by non-partners. Partners remain faithful despite injuring and reproductive incapacity. If one of the pair is removed or dies, the remaining partner will often taken many weeks to find a replacement (Vincent and Sadler, 1995).

However, there seems to be a few exceptions, in species like *H. abdominalis,* in which case neither pair fidelity nor greetings have been detected in a few brief studies (Lovett, 1969; Filluel, 1996), and no greetings have been seen among apparently paired *H. comes* (Lourie *et al.,* 1999a).

It is still not known how pairs originally form, or about their long-term duration in any species of seahorses. Possibly for a slow moving animal like seahorses that are thinly spread in the wild, finding new mates would require considerable time and energy. So males perhaps sequester their females by mating in synchrony with neighbouring males, as reported in the case of *Malacanthus lotovittatus,* a Red Sea tile fish, with females so widespread that a male can 'sequester' only one female at a time, and new mates are not readily available (Clarke and Pohle, 1992). The compensation for monogamous females might be greater reproductive efficiency, quicker egg transfer and larger broods (Vincent, 1994).

The unusual reproductive mode of seahorse provides certainty that they do not mate with non-partners. Uniquely perhaps, both male and female seahorses provide visible evidence of having mated, the female girth diminishes and the male pouch fills (Vincent, 1996). Male and female reproductive state changes are always synchronised within a pair and only within a pair, confirming that they are faithful to each other. Such sexual fidelity to one partner is extraordinarily rare among animal species, DNA evidence reveals that most animal species, including many birds, practicing firm social pairing, are often not sexually faithful, and mate with non-partners as well as partners (Vincent, 1996). Even social pairing is uncommon in fishes, and previously unconfirmed in any species from a soft bottom marine habitat (Barlow, 1984).

2.5.1.7. Courtship and Mating Patterns

The breeding rituals of a paired seahorse culminate in mating, when the female transfers the hydrated eggs into the brood pouch of the male by means of a prehensile ovipositor. Courtship in seahorses commonly lasts a long time. For instance, in *H. whitei*, the male and female of a pair change colour, then grasp a common hold fast and pivot around it for up to nine hours, periodically leaving it to promenade across the bottom, with their tails entwined (Vincent and Sadler, 1995). The pair will also tilt towards each other and quiver.

Given their dependence on camouflage, it is surprising that seahorse courtships are colourful, active and lengthy. During the last few hours of courtship, the female begins to point her snout up towards the water surface, rising on her tail tip. In the same period, the male begins to pump, jack knifing his tail to meet his trunk, thus forcing water in and out of the dilated pouch opening (Vincent and Sadler, 1995; Vincent, 1994 a; Masonjones and Lewis, 1996). Eventually the pair raises through the water, with the male also beginning to point, so that the female can insert her ovipositor into the open pouch of the male. It may take many attempts for the female to align her ovipositor with the male's pouch opening, and the pair finally lock together at mid-water. The female then transfers long sticking strings of eggs into the male's pouch. The partners then separate, and drop to the bottom, where the male gently sways from side to side to settle the eggs in the pouch. A female's body visibly deflates after egg transfer, while the male's pouch inflates, which almost always occur simultaneously. Neither sex remates during the male pregnancy.

Males compete more to get pregnant than females do to give away the eggs in both *H. fuscus* and *H. zosterae* (Vincent, 1994 a; Masonjones, 1997). Both sexes compete for mates, but males showed higher levels of behaviours common to both sexes, such as intruding and colour changing (Lourie *et al.*, 1999a). Male *H. fuscus* also exhibit two sex-specific aggressive behaviours like tail wrestling with a rival or snapping (flicking their snouts at his head), whereas females have none (Vincent, 1994 a).

During the reproductive season, males with empty pouches can be ready to mate very quickly whereas females need to hydrate eggs before mating. Unmated males are thus able to mate before unmated females, and this difference in rate appear to promote male competition for mates (Vincent, 1994 a; Masonjones and Lewis 2000). However, in the case of pregnant males, during the reproductive season, both sexes have usually mated recently and the male must finish his pregnancy before remating. Experimental work on *H. fuscus* showed that the female would sometimes have been able to mate before her partner had given birth, but she did not take this opportunity, presumably partly because of their enduring pair bond (Vincent, 1994 b).

2.5.1.8. Male Pregnancy

The unusual mode of reproduction in seahorses in which the male becoming pregnant appear to be the most extreme form of male parental care yet discovered, although it arises from a general bias towards paternal care among fishes. The female seahorse deposits eggs in the male's brood pouch, where they are fertilized. The male seahorse's brooding can justifiably be called a pregnancy, given the intimate association of parent and offspring (Vincent, 1996), closely resembling that of mammals.

As the reproductive season begins, the epithelial tissue walls of the male's pouch thicken in preparation for embryonic development (Boisseau, 1967 a), and this state is maintained throughout the season. The eggs are fertilized inside the pouch by the male's sperm. Each embryo then embeds in the epithelial tissue, lining the pouch wall, and the surrounding capillaries supply oxygen to the embryos (Boisseau, 1967 a).

There has been speculation on the male's role in nourishing the young, but work in the 1960s (Boisseau, 1967 a), partly confirmed by recent research (Masonjones, 1997), indicates that most nutrition comes from mother. The egg yolk provides nutrients, while the male secretes the hormone prolactin that induces enzymatic breakdown of the chorion to produce a placental fluid (Boisseau, 1967 b). This maternally derived fluid bathes the protruding part of the embryonic sac. The male contributes calcium to the embryos, possibly assisting in skeletal development (Linton and Soloff, 1964), and may also provide some other compounds. The male also regulates the pouch environment, altering it from being like body fluids to being like sea water (i.e. more salt, and less calcium), as pregnancy proceeds (Linton and Soloff, 1964), which should ease the transition of young from the pouch to the sea. The apparently greater maternal contribution to placental fluid and nourishment does not necessarily mean that females contribute proportionately more of their available resources, in total, to the offspring, than the males do. It seems probable that the male may make a greater relative contribution to the embryos during pregnancy than the female does during egg preparation (Vincent, 1994 b). Pregnancy of the male seahorses lasts ten days to six weeks, depending on species and water temperature, being shorter at higher temperatures (Vincent and Sadler, 1995).

2.5.1.9. Birth and Juveniles

At the end of the period of pregnancy, the male goes into labour, usually in the dark early morning hours, pumping and thrusting for hours before finally ejecting fully independent young. The hatchlings receive no further parental care, and in contrast to the adult, are very vulnerable as prey. Newborn seahorses are commonly 6-12 mm long, with much less variation among species in young size, than in adult size (Vincent, 1990). Strawn (1958) reported that the new born young in two broods of *H. zosterae* from Cedar Key, Florida replicas of their parents, although there are differences in body proportions like the juvenile having a shorter or longer snout in relation to the head depending on elongated body and tail, and more pronounced spines and coronet than adults (Ginsburg , 1937; Gomon and Neira, 1995).

Young of many seahorse species, apparently spend their first few days drifting in the water column, while those of a few others attempt to settle to the bottom within hours (Lourie *et al.,* 1999a; Graham, 1953). The duration, distance and significant of juvenile dispersal remain unstudied. These factors have significant effect on rates and sources of colonisation, and are thus important for conservation and management of exploited populations. Growth and survival rates at all seahorse life history stages also need careful research.

2.6. Fishery exploitation of seahorses

2.6.1. Uses of Seahorses

2.6.1.1. Seahorse in European Medicine

The unique medicinal properties attributed to seahorses formed the basis of a well established trade; a huge trade in terms of volume and value, given the small size of this fish. The uses of seahorses have been varied. Apart from being used in medicines, it is a favourite ornamental fish. Dried seahorses are also used to make interesting curios.

Seahorses have long been credited with magic and medicinal value in Europe. The Greek philosopher Plutarch (Circa 46-120 AD) saw the seahorse as a symbol of impudence "the creature being said first to slay his sire and then force his mother" (Whitley and Allen, 1958). Apparently Greek fishermen thought that the seahorses were the miniature offspring of horse-sized parents that pulled Poseidon's chariot.

European reports of medical use of seahorse are apparently older than Chinese records. A succession of late Greek and Roman writers, from as early as 342 BC (Menander, Strabo, Philostratus, Dioscorides, Aelian and Pliny) drew a complex picture of the medical applications of seahorses (Eastman, 1915); seahorses when roasted, prevented the retention of urine; oil of roses in which a seahorse has been dipped and killed was effective against chills and fever; ashes of seahorses mixed with liquid pitch, tallow, and oil of sweet marjoram cured baldness and pain in the sides; ashes of seahorse in wine would lead to spasmodic coughing, hot flushes in the head, discharges from numberstrils, a fleshy odour, swelling of the abdomen and finally death. Seahorses have also been credited with curing hydrophobia (rabies) and infertility. Pliny the Elder, the Roman natural historian (23-79 AD) specifically cited seahorses as agents against leprosy, seahare venom, bites from mad dogs, and baldness (Vincent, 1996).

Western medicinal use continued until at least the eighteenth century. More recently, however, seahorses have been consumed by West as aquarium pets, souvenirs and curios.

2.6.1.2. Seahorses in Traditional Chinese Medicine (TCM)

The World Health Organisation recognises TCM and other traditional medicines as viable health care options for which national Government support is solicited (Anon 1994a). TCM is practised in China, Hong Kong, Taiwan, Singapore and ethnic Chinese communities worldwide. It is known as *hanyak* in Korea, and *Kanpo* in Japan, and exerts greater influences on the Jamu medicine in Indonesia, which is an indigenous form of medicine heavily reliant on plant products, and the folk healing practices existing in other areas such as the Central Philippines.

The Central tenants to the philosophy of TCM are *yin* and *yang*, which can be understood as two polar complements, and neither of which can exist without the other, just as dark and light that can only be understood in the context of each other (Kaptchuk, 1983). *Yin* denotes illnesses that are characterised by weakness, slowness, coldness and under activity, whereas those that manifest strength, forceful movements, heat and over activity are *yang* (Kaptchuk, 1983). Treatment involves assessing six environmental factors (labelled for illustrative purposes as Pernicious Influences or Evil: Wind, Cold, Fire or Heat, Dampness, Dryness and Summer Heat) that are recognised as playing a part in disease, and can enter the body when the equilibrium between *yin* and *yang* is upset (Kaptchuk, 1983). The idea of causation central to Western medicine is absent from TCM Chinese patients will often employ both schools of medicine tending to use Western medicine in acute and emergency situations and TCM in chronic situation). Some TCM treatments, such as that are effective for eczema, are being adopted in the West too (Kaptchuk, 1983.

The *Chinese Pharmacopoeia* lists five seahorse species; *H. histrix, H. japonicus, H. kelloggi, H. kuda* and *H. trimaculatus* (Anon, 1985). Another medical tome cites seven useful seahorse species. *H. coronatus* (crowned seahorse), *H. histrix* (thorn seahorse), *H. japonicus* (small seahorse), *H. kelloggi* (wrinkled seahorse), *H. kuda* (large seahorse) *and H. trimaculatus* (three spotted seahorse) as reported by Li Yue Cheng (1994).

2.6.1.3. Seahorses in other Asian medicines

Seahorses are used to treat asthma, gas pains, and hyperactivity in the Central Philippines (Alino *et al.*, 1990). They are also employed in Indonesia's Jamu medicine. Details of Jamu medicine are kept secret, but men from Java, Bali and Sulawesi certainly ingest seahorse-based Jamu aphrodisiacs (Vincent, 1996).

2.6.1.4. Seahorses as aquarium fishes

The unique morphology and behavioural characteristics make seahorses one of the most favoured marine ornamental fishes. Virtually all aquarium seahorses come directly from the wild. Aquarium seahorses are usually one of the four or five species, of which one is a member of the *H. histrix* complex (pale and spiky) and three are from the *H. kuda* complex (smooth and either yellow, black, or Tiger tail-striped). The fifth aquarium species is *H. erectus* (usually lined) caught off Florida (Vincent, 1996)

Seahorses are usually highly unsuitable aquarium fishes and are among the most difficult of fishes to rear, as few survive long in captivity and often suffer severe physiological damage during collection and transport. They are often the hapless victims of poor aquarium management at the captive facilities of wholesalers or retailers, importers and hobbyists, and are easily prone to diseases. Owing to a lack of good information on their husbandry, they are subject to starvation due to insufficient and/or unbalanced diets, and incompatible aquarium inhabitants (Vincent, 1996; Lourie *et al.,* 1999a). Although they survive the process of capture and shipment quite well, they later die partly as a consequence of these reasons.

Adult seahorses require a steady supply of varied live foods in captivity, and a high level of cleanliness because of their vulnerability to fungal, parasitic and bacterial ailments (Vincent, 1996). Being captured by crude methods abrades their skin; being held in crowded and often unsanitary conditions increases their vulnerability to diseases; and being starved (as is commonly the case) and malnourished for weeks exacerbate later husbandry problems. Those seahorses that do live will often mate readily in captivity, but the ensuing young seldom survive long because of problems in supplying appropriate food and vulnerability to disease

(Vincent, 1996). Captive-bred young seahorses usually signify merely that the pregnant male was caught in the wild and give birth in captivity. Aquarists whose seahorses die commonly purchase more of these fishes, thus ensuring a steady market for seahorses.

2.6.1.5. Seahorses as curios

Dead seahorses are popular curios partly because they retain their shape and details when dried. Dried seahorse souvenirs are being kept for sale in beach resorts and shell shops around the world. Seahorses are used for making paperweights in glass with the animals embedded within. Huge piles of seahorse key chains, with the rings punctured through their eyes, were on sale on beaches in Thailand in 1989 (Vincent, 1996). Jewellers also dip the dead animals into paint or spray them as earrings or brooch.

2.6.2. Seahorse fishery and species distribution

There are at least 32 species of seahorses all over the world (Lourie *et al.*, 1999a). They are generally caught by artisanal or subsistence fishers, or as a by-catch of trawling. Although the intensity of effort dedicated to collecting seahorses depends on their availability relative to other fisheries resources, as well as on other income earning opportunities, seahorses may now comprise up to 80% of fishers' annual incomes, and up to 100% of the money earned during the peak seahorse catch months Vincent, 1996). In many exploiting nations such as in India, Indonesia and the Philippines, seahorses *per se* have increasingly become the goal of fishing trips, or have become the main source of cash from a trip otherwise dedicated to obtaining seafood (Vincent, 1996).

Large scale mechanised fisheries for seahorses are unknown and are unlikely ever to be viable. Seahorses move slowly, and are often found in areas that are difficult to access with fishing gear such as coral reefs or mangroves. However, seahorses that are commonly landed as an incidental by catch from shrimp trawling and other forms of net fishing have become the important contributors to the seahorse trade in many areas, such as India and Thailand.

2.6.2.1. China

Wild seahorses are found along the Chinese coast among seaweed and in sea grasses, from Vietnam to Korea. Based on a tentative assessment, Vincent (1996) observed that the seas adjacent to China might contain about seven species of seahorses, although their taxonomy remained confused. Vincent (1996) named five species having commercial value as *H. trimaculatus, H. kelloggi, H. kuda, H. histrix* and the smaller species *H. coronatus.*

The main domestic sources in China were reported to be the Gulf of Tonkin and the South China Sea. The seas around Fujian Province were also rich in seaweeds, but no longer yielded many seahorses. The Gulf of Tonkin was home to at least two species (*H. trimaculatus* and *H. kelloggi* types) and other species were found around the Southern coast of Hainan Island. The Gulf, which had a mean depth of only 40m, and rich in seaweeds and edged with mangroves was heavily trawled. There were no reports of seahorse catches in Chinese Seagrass areas or estuaries, which might reflect lack of monitoring, rather than lack of fishing (Vincent, 1996).

Seahorses were generally obtained in China, as a by -product of trawling for food fishes as there was no known target fishing (Vincent, 1996). They might also be caught in throw nets or while holding onto the gill nets set in mangroves to catch food fishes. The domestic harvest of seahorses was very small and production very variable. The total catch per boat was only a few seahorses to a few metric catties of total fish haul in the Southern Provinces, in 1993 (Vincent, 1996). Such volumes however could amount to a substantial number of seahorses, if many boats were active.

2.6.2.2. Hong Kong

Hong Kong is a major entrepot for seahorses. Hong Kong imported seahorses for domestic consumption for processing (bleaching) and export back to source countries, and for re-export to China or Taiwan and other consumer countries.

Seahorses in Hong Kong were caught locally until the 1970s, mostly as an incidental by catch, in the South China Sea off Donghsa (Pratas Islands) and Xisha (Paracel Islands). Seahorses caught near Hong Kong and other smooth types of seahorses were considered to be the highest grade; but the local production would meet only 50% of the demand so that most seahorses must be imported (Vincent, 1996). Apart from by catch, seahorses would also be collected near shore, along with other fishes, often among brown Sargassum or other algae, with the aid of a butterfly net (Vincent, 1996).

2.6.2.3. Singapore

Singapore's geographic location, its frequent role as an entrepot for many commodities, and its ethnic Chinese population of 2.2 million people would suggest that it traded large volumes of dried and live seahorses. Large boxes of seahorses were often seen for sale in retail outlets in Singapore (Vincent, 1996).

Most of the annual exports of dried seahorses from the Southern coast of India (nearly 3.6t) were destined to Singapore (Marichamy *et* al, 1993). Singapore has become a major hub of international aquarium trade. Most of the aquarium seahorses caught in the rich habitats of Western Indonesia went overland to Singapore for sale and further export. Singapore was one known source of seahorses for North American aquarium hobbyists (Vincent, 1996)

2.6.2.4. Taiwan

There had been no precise descriptions of the seahorse species found in Taiwan waters, except Lee (1983) who reported *H. erinaceus, H. histrix* and *H. trimaculatus*. Shen S-C (1993) cited three species to be *H. kuda, H. kelloggi* and *H. aterrinus*.

Vincent (1996) observed at least five seahorse species to be in Taiwanese TCM outlets, including two large thickest species and three smaller species. According to Vincent (1996) the large species was incorrectly claimed to be *H. trimaculatus* and it might have been *H. kelloggi*. Vincent (1996) also noted another species in the TCM shops probably *H. coronatus*, which was found near Japan.

2.6.2.5. Japan

Seahorses were known as *tatsunootoshigo* in Japan, translated as "offspring of the dragon". At least six species of seahorses occupied Japanese waters, ranging in adult size from 60mm to 180mm. None of the species, which included *H. coronatus, H. histrix, H. japonicus, H. sindonis* and *H. takakae* had been studied in detail (Vincent, 1996).

2.6.2.6. The Philippines

2.6.2.6.1. Species composition

Seahorses in the Philippines live in seagrass beds, mangrove and coral reef areas, often in water that is only one to two metres deep. They were found more densely in seagrass habitats nearer to mangroves, than in those farther from mangroves. The Philippines is a major exporter of seahorses for TCM, for aquarium hobbyists in Asia and the West, and for curios globally.

Most seahorses in the Philippines were broadly classified as "yellow" or "white", or "black", and a few rare types including "red", "giant" and "tiger". There might be at least 8 species of seahorses in the Philippines, or probably more (Vincent, 1996). The name 'yellow' seahorses embraced a complex of several species, including one of the *H. histrix* type, a spiny cream-coloured seahorse with distinctive brown bar markings around its snout and radiating from its eyes. This species had for sometime been dried as a novelty item or exported for aquarium use (Schroeder, 1980). Other species within the 'yellow' complex were not spiny. Yellow seahorses yielded higher prices in the aquarium trade, because they were preferred by foreign hobbyists, for aesthetic reasons. Palawan and Busuanga, where yellow seahorses were found primarily in seagrass beds, dominated the live seahorse trade. On Bohol, yellow seahorses blended well into the slopes of yellowish rocks and corals found along the coast (Vincent, 1996).

At least one of the seahorse types described as 'red' was another of the *H. histrix* complex, with longer black-tipped spines. But the designation 'red' might also include other species, since it was variously claimed to have fine red stripes, or were even to be solid red. They might be variants of yellow seahorses from different habitats, or were distinctively different types from deeper waters. Most reports of red seahorses came from Cavite Province of Luzon (Vincent, 1996).

Black seahorses comprised at least 3 species, including several of the *H. kuda* complex. The most common type was found in coral reef areas, with a second type in seagrass beds and a third in deeper waters. 'Black' seahorses came from all over the Philippines, and most seahorses in Bohol were 'black'. They were known as 'bald seahorses' since they lacked spines. Live seahorse traders considered 'black' seahorses to be a by-catch of the harvest for 'yellow' seahorses because hobbyists would buy any size of yellow, but only large black seahorses (Vincent, 1996).

'Tiger' seahorses had distinctive black and yellow bands across the tail and on parts of the trunk. They apparently came from seagrass areas, but were rare in most of the Philippines. *H. trimaculatus* was another obvious species, which might be one of the yellow seahorses. There were also different varieties described like ' Jungle', 'chequered' 'spotted' and 'orange' in the Philippines Vincent, 1996). The uncommon 'giant' seahorses were highly priced in the dried seahorse trade. They were primarily a trawl by-catch from deeper waters around Negros in the Central Philippines (Vincent, 1996).

2.6.2.6.2. Fishing Methods

Seahorses in Philippines, were most commonly collected by hand, but also with scoop net, push net, beach seine or trawl net. This was an open access fishery, with all seahorse collectors entitled to fish the same areas, although small marine reserves and sanctuaries were beginning to proliferate (Vincent, 1996).

Hand collection was done early morning, in shallow waters, of only 1-2 m deep, clearing the surface of debris so that they could search the seagrass beds. It was easiest to work when the water was shallow, less than 0.5m above the top of the seagrass. Seahorses were spotted by their tail, snout or flashing fins and caught with a small scoop net, made from a circle of netting stretched over a 125-150mm diameter ring attached to a two meters bamboo pole. Seining was done during rough weather, when visibility was less, employing a seven meter long net, collecting only two to five commercial sized seahorses per haul, and the same number of small ones, which were being returned to the sea, in 1993 (Vincent, 1996). Live seahorse fishers of Palawan also usually worked in shallow seagrass beds, during daytime. Most of them hand collected, but they also used push nets in waist deep water (Vincent, 1996).

Collection of live seahorses in the Busuanga area included a form of outrigger boat (*banca),* which was a bamboo raft apart from hand collection. The local buyers collecting seahorses might hold them in cages in the sea for up to a month, with supplementary feeding. They were then packed in plastic bags, which were placed in straw bags and taken by boat or flight to Manila (Vincent, 1996).

Bohol fishers worked at night, when it was said that their seahorses were easier to find, which might represent a relatively recent shift from diurnal habits (Vincent, 1996). Many Bohol species lived in complex Sargassum and coral habitats, whereas seahorses in Palawan were largely found among seagrass. The seahorse fishery that began in 1966 soon became a vital fishery, providing important income for local fishers; one third of those in one village, viz. Handumon, relied on seahorses. Most fishers free-dived in shallow water, guided by lanterns attached to the outriggers of their small *bancas*. Some, however, dived in deeper water (12 to 15m depth) breathing compressed air from the surface, and lighted their way with headlamps. The lengthy dives and unreliable air supplies made this a dangerous practice (Vincent, 1996).

In the Roxas (Palawan) area, the fishermen worked by day, and relied on a 'baby trawl' and hence accumulated many dead seahorses in pursuit of live animals. In 1993, fishers could collect up to 300 seahorses per trawl, if they targeted seahorses, with a maximum of four trawls daily. In hot weather fishers needed to land seahorses after only one trawl, if any should have survived, and so hand collection was more common. About 50% of all live seahorses caught in Roxas died before they reached the dealers in Puerto Princessa, despite careful attention enroute (Vincent, 1996).

The anchovy and shrimp fisheries obtained some seahorse by-catch in the Philippines, but volumes were unknown. 'Giant' seahorses were usually obtained as incidental catch of deep-water trawling.

2.6.2.6.3. Timing of seahorse catch

Seahorses were apparently more easy to catch in the shallower water of low tides and difficult before and during storms, perhaps because they hid in the substrate. It was also reported that the catch increased around new and full moons, perhaps because the greater tidal range created shallower water (Vincent, 1996).

Aquarium dealers used to get seahorses year round, but usually obtained much earlier in the year. In most of the Philippines, fewer seahorses were available during the rainy seasons (roughly June to November). The Bohol seahorse fishery was typical, being intense in December to May, after which the fishers concentrated on other species such as squid or abalone, *Haliotis* spp; there being however, no rigid rules existed.

2.6.2.7. Thailand

Thailand was a major exporter of seahorses, perhaps exporting around 15 t annually (Vincent, 1996). If this estimate was true, Thailand was the largest exporter of seahorses. The seas around Thailand included at least five seahorse species, of which at least two were extensively fished; one *H. kuda* type and one *H. histrix* type. Both had generally been considered abundant on the east coast of Thailand (Vincent, 1996).

Most seahorses were caught in Thailand as a by-product of the shrimp trawl net fishery. Fishers commonly obtained 30-50 seahorses in each trawl (usually *H. histrix* type) with maximums of 50-100 seahorses per haul. A target fishery for seahorses also existed in Thailand, dating back at least to the late 1970s. Pairs of fishermen used to go out in small boats (5-6m in length), equipped with a small mesh trawl net intended specifically for seahorses. Usually seahorses of *H. kuda* type lived in about 3-5m of water depth (Vincent, 1996).

In the Gulf of Thailand, seahorses were generally fished during the winter (non-monsoon season) from October to February, which was probably coincident with the breeding season for these seahorse species in Thailand. It was said that seahorses moved offshore in the summer (Vincent, 1996).

2.6.2.8. Vietnam

2.6.2.8.1. Species composition

Vincent (1996) reported that at least seven species of seahorse were found in Vietnamese waters, but their taxonomy was confused. However, *Lourie et al.,* (1999b) made detailed investigation on the taxonomy and identified seven species of seahorses such as *H. spinosissimus, H. comes, H. trimaculatus, H. kuda, H. kelloggi, H. mohnikei* and *H. histrix in* Vietnam.

Seahorses lived among coral reefs and sea grass beds and in estuaries along the coast of Vietnam. They were also found on soft bottoms, among mollusc shells, and amid algae. Pregnant males of at least some species appeared to breed year round, but the peak of spawning varied among species (Truong Si Ky and Doan Thi Kim Lam, 1994). *H. trimaculatus* was the most common species on sale in Vietnam (Vincent, 1996).

2.6.2.8.2. Seahorse catch

Fishers from Kien Giang Province in the extreme Southwest caught more than half the traded seahorses in Vietnam. They were primarily landed as a by catch of the coastal trawl fisheries, but a few were also hand collected by divers or swimmers seeking a wide range of animals. Seahorse fishing was not an organised activity, even in areas with large output (Vincent, 1996).

Seahorses were caught all the year round. With particularly high numbers in February to July, trawlers operated more frequently, because the seas were calm and clear. Many boats obtained seahorses as by catch. They could be trawled from deeper waters. Offshore seahorses could apparently be landed from most trawls, but more were available near coral reefs, and more were landed during the northeast monsoon (October-February). Usually the seahorse landings comprised only an insignificant portion of the total fish catch by weight. The wet weight of seahorses obtained as by-catch was only 2-3 tonnes (Dao Xuan Loc and Hoang Phi, 1991), while the total fish production in Khanh Hoa Province was 38,500 tonnes, in 1992 (Vincent, 1996).

2.6.2.9. Indonesia

Indonesia was a major exporter of live seahorses for the marine aquarium trade, mainly to Australia, Europe, North America and Taiwan. However, the country exported only small quantities of dried seahorses for TCM, most of the dried seahorses being used for the domestic trade for Jamu medicine and for curios (Vincent, 1996).

2.6.2.9.1. Distribution and species composition

Indonesian seahorses were inshore fishes (eg.200m within shore in northern Sulawesi) and were said to occupy seagrass (Ambon, eastern Java, Bali, northern Sulawesi) and mangrove (Bali) habitats; but could also live in corals (northern Sulawesi) and even over sand (Bali). Areas where seagrasses, mangroves and corals met (e.g. northern Sulawesi) were thought to provide excellent seahorse habitats. Seahorses were estimated by fishers at densities of around 0.2-1.0 seahorses per square metre in eastern Javan sea grass beds, and at fewer than 0.1 per square metre among northern Sulawesi corals (Vincent, 1996).

Indonesia was rich in seahorse species but their taxonomic identification remained unclear (Vincent, 1996). Although colours were inadequate identifiers of seahorses, they could serve as general clues to species. Anecdotal description suggested that Central Indonesia might have six species of seahorses, which however, required confirmation from genetic analysis. The largest dried seahorse seen Indonesia (from near Manado in northern Sulawesi) measured about 200mm long (Vincent, 1996).

2.6.2.9.2. Target fishery for live trade

Seahorses were targeted for the live trade only in those areas near the major international airports, Jakarta and Denpasar. These areas included eastern Sumatra, Java, Bali, and West Nusa Tenggara (Lombok and Sumbawa). Small target catches for the dried trade had been reported near Manado (Sulawesi) and around some islands in the Moluccas. Fishers in other areas of Indonesia sold dried seahorses from by-catches (Vincent, 1996).

Collectors in eastern Java and Bali targeted seahorses for the aquarium trade. Some were caught by hand, some in beach seines, and others by push nets or scoop nets. The fishers on Palau Serangan used to wade in shallow water over the seagrass beds, seeking seahorses through the water surface. They swam with face marks when water was rougher. Fishers would either dive to pick the seahorses by hand or employ a long-handled deep net, like a butterfly net, to scoop the seahorses. At night, two collectors working together would employ a nylon beach seine or barrier net measuring about 15m long. Collectors might travel up to three hours before beginning to fish (Vincent, 1996).

Seahorses were collected among the seagrass meadows near Lampung & Sumatra. Fishers targeted shrimps, but also sought seahorses, fishing by day using a small one-person push net. They obtained *H. kuda* type species, which they sold to Jakarta for the medicine and aquarium trade. Aquarium dealers sold all dead seahorses to either TCM or to Jamu (Vincent, 1996).

2.6.2.9.3. Target fishery for dried seahorses

Most seahorses caught near Manado (Sulawesi) came from seagrass beds. There was no intensive fishery for seahorses, but some were hand-caught by swimmers during the daylight hours, usually in about one metre of water. Seahorses were also collected when found holding onto the fine barrier nets that were placed on reef crests to catch fishes on the ebbing tide, or were picked up when encountered on fish corral traps (Vincent, 1996).

Children in the Moluccas used to dive for seahorses, largely as a game, but also sold them to aquarium product dealers and dried fish merchants. The children would find them at low tide, put them in sun to dry and give them to Chinese merchants on the island in exchange of sweets. Swimmers in Ambonese seagrass beds also caught some seahorses, particularly during the dry season (November to March). Kai Besar, the larger of the Kai Islands, also had a small seahorse fishery with a variable catch. They were caught in seagrass beds at night, using lanterns, in very shallow water. The fishers sold the seahorses to ethnic Chinese merchants (Vincent, 1996).

2.6.2.9.4. Season

Seahorses were apparently available all year in Southern Bali with slightly more in the rainy season (January and February). Nearby Javanese buyers received far more seahorses (hundreds per week) from January to July, which coincided with the January to April rainy season in eastern Java, and the period immediately thereafter, when seahorses were apparently easier to find in the calmer Seas (Vincent, 1996). Exporters from Bali also used to get peak collections during the rainy season. Seahorses apparently bred in eastern Java during the dry season, i.e. July to January (Vincent, 1996).

Seahorses were readily available in the Manado (Sulawesi) region during the west wind season (early in the year). They might then be breeding and thus becoming more accessible (Vincent, 1996). Only a few could be found by June, and they might migrate offshore.

2.6.2.10. India

2.6.2.10.1. Species composition

Seahorse fishing and trade in India appeared to be restricted to two southern States, Tamil Nadu and Kerala, although little was yet known about the latter (Vincent, 1996). In Tamil Nadu, a well-established fishery and trade existed in the Palk Bay and Gulf of Mannar coasts. Hand collecting near shore (from small boats) at Palk Bay was reported to obtain a species in the *H. kuda* complex, studied in the laboratory as *H. fuscus* (Vincent, 1990, 1994a, 1995b). This species, which measured up to about 180 mm (mean 110mm, wet length) was found in seagrasses, often grasping sponges.

Shrimp trawling farther offshore (in larger boats) brought a species (or possibly two species) resembling *H. trimaculatus* with a maximum size of perhaps 100mm. Probably a third (or fourth) species was caught in Kerala (Vincent, 1996). Vincent (1996) also reported that the Kerala seahorses could measure 300mm and were heavy with only about 100 animals per kilogram. The *H. fuscus* and *H. trimaculatus* type, however, weighed 350-500, and 800 seahorse per kilogram (Vincent, 1996). The recent laboratory findings by Lourie (2000, pers. comm.), however, indicated that there were at least 5 species of seahorses that abound in Indian waters.

2.6.2.10.2. Uses of seahorse in India

Seahorses were occasionally used as medicines in Tamil Nadu, with a limited role in curing whooping cough in children. The Seahorse was powdered, roasted in an earthenware pot and then mixed with honey to administer. Older people also believed that dried seahorse powder with honey would relieve asthma, in a remedy akin to those in TCM (Vincent, 1996).

2.6.2.10.3. Seahorse catch in India

In Tamil Nadu fishery was concentrated in the Ramnad district. There existed a target fishery for seahorses in the Palk Bay area, whereas, the seahorses were landed as by-catch in the Gulf of Mannar. The Gulf of Mannar being rocky appeared to provide a less suitable habitat for seahorses, whereas the Palk Bay had seagrass and sponges. Moreover, the fishers in the Gulf could still obtain sea cucumbers and chanks (conches *Xancus pyrum)*, in sufficient numbers to obviate the need to earn more money than targeting seahorses. Seahorse by catch was also landed farther north in Pondichery, but rough seas and deeper waters precluded a target catch there (Vincent, 1996).

2.6.2.10.4. Target fishery for seahorses in Palk Bay

Seahorses had been collected in Palk Bay since at least 1977. Marichamy *et al.* (1993) observed that the heavy demand for seahorses in the international market and the decline in sea cucumber fishing triggered a sudden spurt of exploitation of seahorses along the Southern Coast of Tamil Nadu. Fishers who collected seahorses also sought other marine resources such as sea cucumbers and chanks. They travelled as far as three kilometres off shore visiting different areas each day, and fished up to five hours in a day, for six days in a week. Wearing a mask and wooden fins, they used to free-dive in waters up to 8 m deep. Several fishers worked together to seek all the seahorses in a small area and then moved on (Vincent, 1996). Seahorses were found throughout the seagrass meadows, at densities of up to 15 per square metre (Vincent, 1996).

2.6.2.10.5. By-catch of seahorses in the Gulf of Mannar

Seahorses were caught incidentally, as a by-catch of shrimp trawling in the Gulf of Mannar. Boats of 11-12 m length were put to sea for 12-24 hours. Most of the trawling was done at night. The number of boats had increased steadily from 1980, and 410 boats operated in one average day in June 1995 (Vincent, 1996). Seahorses were extracted by sorting through the voluminous by-catch associated with the shrimps (estimated shrimp to by-catch ratio of 1:19). Each boat typically used to get 1-4 seahorse per day each, but catches of 10 seahorses were fairly common, and those of 25 also used to occur. Restrictions had been introduced for fishing by the boats to three fishing days weekly in order to reduce fishing pressure but many boats had doubled their working time from 12 to 24 hours to compensate for this (Vincent, 1996). Women were active in the Gulf of Mannar fishery, mostly in sorting the by-catch (Vincent, 1996).

2.6.2.10.6. Season

Vincent (1996) reported that Palk Bay fishers collected most seahorses either by March and October, or some times April to June. The trawl fishery in the Gulf of Mannar operated year round, but fewer seahorses would be caught from August, when monsoon winds limited fishing effort (Vincent, 1996). The fishing for seahorses coincided with their breeding season (Vincent, 1996).

2.6.2.10.7. Dried Seahorse trade in India

2.6.2.10.7.1. Trade routes

Most seahorses from Tamil Nadu were exported to Singapore, often via Madras; but some went to Malaysia (Marichamy *et al.,* 1993). Occasionally Chinese merchants usually from Singapore had approached buyers directly to obtain seahorse. It was claimed that the Tamil Nadu seahorses were sold as "top quality" in Singapore. The good drying process, and the smooth texture might have been the factors for their quality (Vincent, 1996).

It was also reported about courier deals in which travellers received free trips to Singapore or Malaysia in exchange for filling their checked luggage with 20-30 kg of dried seahorse (Vincent, 1996).

2.6.2.10.7.2. Volume of dried seahorse trade

Field surveys conducted by Vincent (1996) indicated that fishers targeting seahorses in Palk Bay sold at least 3040 kg of seahorses annually. That meant at least 1.2 million individuals, based on an estimate of 400 per kilogram. One of the three shell shops that bought seahorses in Rameswaram obtained around 100 kg annually. Trawlers might have extracted at least 300 kg annually, or 2,40,000-3,00,000 of these much lighter seahorses. This figure would be reached by Rameswaram fishers alone, if each of the 410 trawlers working on one average night in June 1995 obtained about 10 seahorses per week, as it seemed possible (Vincent, 1996). Kerala seahorses were reported to have contributed a further one kilogram per day to Ramnad district buyers, approximately 350 kg annually or 3,50,000 of these larger seahorses (Vincent, 1996).

A conservative estimate was arrived by Vincent (1996) as at least 3600 kg (about 1,500,000 dried seahorses) of seahorses in trade annually from the Southern coast of India (Vincent, 1996). Marichamy *et al.* (1993) estimated the local exports of seahorses as 300-400 kg dried seahorses per month in 1992, which would amount to a total of 3600-4800 kg annually. Vincent (1996) also reported that these volumes had again increased to 4800-6000 kg *per annum* or 400-500 kg per month, of dried seahorses exported from the Southern coast during 1995.

2.6.2.10.7.3. Value of dried seahorses traded in India

Vincent (1996) reported that the prices of dried seahorses have increased substantially since the target seahorse fishery surged in growth in 1989 or 1990. In 1995, fishers received Rs.0.5 to Rs.15 per seahorse according to size with most worth Rs.12. Second level buyers were paid from Rs.2000-5000, but most received about Rs.2000-3800 per kilogram for dried seahorses according to size and perceived quality. Big sized seahorses were sold to the buyers in Kilakarai at Rs.10,000 per kilogram (Vincent, 1996).

Women sorting through trawl by-catch were usually paid Rs.1 to Rs.2 per seahorse of 30mm and 70mm long respectively. The buyer received Rs. 2000 per kg for seahorses under about 75mm and Rs.3500 per kg for those at least 75mm long.

2.6.2.10.7.4. Economic importance of seahorses in Southern India

Marichamy *et al.* (1993) observed that the fishers considered the advent of seahorse fishing a boon because income from sea cucumber catches were declining. The seahorses had become economically important to the villagers. Most fishers earned half of their annual income, or some even cent percent, from seahorses. Most buyers also dealt in other marine animals like cephalopods, shark fins, sea cucumbers, fish intestine, air bladders, chank and pipefishes.

The total export value of the seahorse fishery in 1992 was at least Rs.800, 000 (US$ 24,932) per month (Marichamy, *et al.*, 1993), but this had probably doubled in 1995 (Vincent, 1996).

2.6.2.10.7.5. Seahorse legislation

The fishery of seahorses had not been subjected to any serious regulations in India, until recently when the Government of India notified the banning of collection and export of seahorses from the Indian coast. Seahorses (all Syngnathidians) were included along with Sharks and Rays (all Elasmobranchii) and Giant Grouper (*Epinephelus lanceolatus*) in Part II A relating to "Fishes", as per Notification S.O.665 (E) of the Ministry of Environment and Forest dated 11th July, 2001.

2.6.2.11. Australia

Australia exported syngnathids, especially pipefishes in large quantities, mainly from Queensland. There had been no import of dried seahorses reported. However, Australia imported live seahorses for the aquarium trade.

Roughly half of the world's syngnathid species were reported to live in Australian waters that included eleven species of seahorses (Munro, 1958; Yearsley *et al.*, 1995). At least five taxonomically tangled Indo Pacific species lived around northern Australia. These were *H. histrix, H. kuda, H. planifrons, H. spinosissimus,* and *H. zebra*. In addition, the very small *H. bargibanti* (13mm adult size) was found on the Great Barrier Reef on a gorgonian fan at 50m depths having previously been recorded only from New Caledonia (Vincent, 1996).

There were five Southern species of seahorses in Australia, which were better defined, although only little was known about most of them. *H. minotaur* was a tiny seahorse (maximum known length 50mm) and was discovered in waters off Southern New South Wales, and eastern Victoria. *H. breviceps* was found from New South Wales to Western Australia, reaching a maximum of 80mm and seldom weighed more than 1.5 g. These two species were not seen for sale in TCM in Australia (Vincent, 1996)

H. whitei which reached a maximum length of 210mm, was largely restricted to sub-tropical waters in southern New South Wales, and was reported to be the best understood Australian species of seahorses (Vincent and Sadler, 1995). *H. angustus* was found only in Western Australia, reaching lengths of 220mm. These two species were probably used for TCM in Australia, but it might be difficult to recognise these species if bleached or mixed into a box of miscellaneous, mid-sized dried seahorses.

H. abdominalis, the largest Australian seahorse species, was found from New South Wales to southern Australia, and in New Zealand, reaching size of 300mm and 25g. Knowledge of *H. abdominalis* was obtained from a short underwater study and several studies in captivity (Lovett, 1969). This species was not used for sale in TCM, but was sometimes sold as an aquarium fish (Vincent, 1996).

2.6.2.12. Europe

Europe primarily consumes seahorses as curios and aquarium fishes. Hundreds of thousands of seahorses were imported to Europe, annually to serve these markets. There were two European species of seahorses, *H. ramulosus* and *H. hippocampus*, which differed primarily in their relative snout length, that of the latter being shorter. Both grow to about 100mm long and have ranges extending from the Bay of Biscay (France) through the Mediterranean to North Africa. *H. ramulosus* might also extend into the Black Sea and Azov Sea (Reina-Hervas, 1989). Both species lived in shallow waters with vegetation, occasionally entering estuaries but their biology was little studied (D'Ancona, 1932; Boisseau, 1967; Reina-Hervas, 1989).

2.6.2.13. North America

Trade records and anecdotal evidence from other nations indicated that the USA might import and export substantial numbers of seahorses both dried and live. Florida recorded many thousands of seahorse landings each year, and was also presumed to be a major recipient of dried seahorses from the Philippines at least. Canada also appeared to import small volumes of dried and live seahorses, while Mexico was reputed to export at least some dried seahorse (Vincent, 1996).

Four species of seahorses occurred in the Americas, three on the east coast and one on the west coast (Fritzsche, 1980; Vari, 1982). Only *H. erectus* reached Canada. *H. ingens* was the sole species found in the eastern Pacific, with a range extending from Baja California, South to Ecuador. It was one of the world's larger species, reaching length of 250mm. The first study of these fishes had been proposed for the Galapagos Islands (Vincent, 1996). This species was being exploited for TCM, and was valuable because of its large size and smooth texture. They were also being sold as aquarium fishes in Europe and North America. (Vincent 1996).

H. reidi was a slender species, approximately 150mm long, living primarily among corals, from Florida throughout the Caribbean and along the Latin American coast, as far south as Uruguay. The minimal understanding of its biology came from one brief study in the wild (Lourie *et al.*, 1999a) and some laboratory observations (Vincent, 1990). *H. reidi* was popular in the aquarium trade because of its attractive colouration. *H. erectus* was a deep bodied seahorse, approximately 150mm long, usually marked with horizontal lines. Its range extended from Canada, throughout the Caribbean, and might continue south to Uruguay. *H. erectus* was often caught off Florida by shrimp trawlers and sold dead and alive. Little of its biology had been studied (Linton and Soloff, 1964; Hudson and Hardy, 1975; Vincent, 1990). *H. zosterae* was a small seahorse (approximately 25mm long) found in the Gulf of Mexico and around Caribbean Islands. Its biology had been investigated by field and laboratory studies (Strawn, 1958; Tipton and Bell, 1983). Although sometimes taken as aquarium fish, its small size precluded its use in TCM (Vincent, 1996).

Seahorses were landed as a by-catch of shrimp trawling in Florida, and were then sold as aquarium fishes or curios. Those seahorses caught by boats trawling for live bait were more likely to be alive when brought to the surface, because nets were raised every 15-30 minutes rather than every few hours, thus subjecting the seahorses to less battering (Vincent, 1996). Fishers were reported to have caught many more seahorses generally (up to 50-100 per boat) on full moons. This lunar coincidence might be related to reproductive behaviour because most males were at an advanced stage of pregnancy when caught, and would have released young soon (Vincent, 1996).

2.6.2.14. Latin America

Some South and Central American nations had at least a minimal involvement in the seahorse trade, but very little was known about trade volumes, values or destinations. There had been some reports of seahorse trade in Ecuador, and that of limited commercial collection of seahorses in Belize, for despatch to Chinese end users when dried.

The four species of seahorses found in North America, viz: *H. erectus, H. ingens, H. reidi,* and *H. zosterae* also occurred in South American waters, and no species were restricted to Latin America (Vincent, 1996). Most of the seahorses were hand collected by hookah rig divers seeking sea cucumbers in the water around the Galapagos Islands, and others were caught incidentally by shrimp trawlers operating in the Golfo de Guayaquil and around the Peninsula de Santa Elena (Vincent, 1996).

2.6.3. Seahorse trade

2.6.3.1 Countries involved

A total of 32 countries or territories were known to sell or buy seahorses (Vincent, 1996). At least 20 countries or territories caught seahorses for export, with volumes ranging from several kilograms to several tonnes per annum. At least 16 nations or territories exported dried seahorses and at least 13 nations imported them, some doing both. At least 16 countries also exported live seahorses to more than 10 countries or territories, most of the live aquarium fish destined to North America and Europe, but also to Japan and Taiwan (Vincent, 1996).

There were five known net exporting countries of seahorses, viz: India, Indonesia, the Philippines, Thailand and Vietnam, and perhaps Malaysia. The Latin American countries such as Ecuador, Brazil and Costa Rica that traded seahorses could also be inferred to be net exporters, since they were unlikely to have large domestic use (Vincent, 1996).

Three countries were known large net importers of seahorses, viz: China, Hong Kong and Taiwan, and perhaps Singapore which was home to about 2.2 million ethnic Chinese, and very small territorial waters where seahorse could be caught. Countries such as Canada, Germany, the Netherlands and the UK, which sold seahorse as curios or consumed seahorses for aquarium pets (but did not have native seahorses) would also be net importers (Vincent, 1996).

Some countries might also re-export seahorses. For instance, Hong Kong imported seahorses from Indonesia and the Philippines and re-exported to the same countries after bleaching the animals. In general, the Southeast Asian nations that used little TCM, exported seahorses to those Asian regions that used more TCM (Vincent, 1996). Asian countries were reported to send aquarium and curio seahorses to Europe or North America, but there was some return trade as well from Italy, Spain and USA. It appeared possible that the USA might be exporting "good quality" dried seahorses to Taiwan and other Asian countries and then purchasing "poor quality" curio-grade seahorses from the Philippines (Vincent, 1996). South and Central America had primarily exported live seahorses to North America and, to a lesser extent, Europe. Asian business involvement in Latin America was increasing and could promote exploitation of seahorses for export to Asia. Large *H. ingens* seahorses from Ecuador were being sent to Taiwan as dried seahorses for TCM (Vincent, 1996).

2.6.3.2. Trade routes

There were in fact several inherent constraints in the assessment of the global trade on seahorses. Most of the trade was undocumented and was being done by clandestine means. This, unlike many of the other economically important species, was the one reason that forced the investigators to rely more on assumptions and situational judgments. A classic research work on the trade of seahorses was done by Vincent (1996), in which she made a comprehensive analysis of the global trade of seahorses. This is the only available work on this billion-dollar trade.

Seahorse trade volumes were large, amounting to many millions of seahorses annually (Vincent, 1996). The involvement was global with at least 32 nations trading seahorses. During 1995, seahorses were selling at up to US$ 1200 per kilogram in Hong Kong (Vincent, 1996), signifying that it is a valuable commodity. These fishes were economically important to artisanal fishes, and medically important to many Chinese consumers. The demand for seahorses invariably exceeded supply, which is likely to grow further, particularly as a consequence of China's economical boom.

Exact quantification of the nature and impact of seahorse trade is difficult because of many reasons. The fisheries and Customs data are sparse and often unreliable. Seahorse taxonomy, geographic distributions and population sizes are unknown and population responses to exploitation are unstudied (Vincent, 1996). Besides the seahorse trade is complex, involving many producers and consumers, most of whom handle only a few seahorses.

Most of the seahorse exports were not sent through recognized channels. For instance, seahorses from India are being sent in checked baggage on flights to Singapore; overseas Chinese carry seahorses when they return to visit China; seahorses are illegally traded between Vietnam and China across the border; merchants tuck seahorses into shipments of sea cucumber from the Philippines; dead seahorses are sent along with live grouper on fast boats from Palawan in Indonesia to Hong Kong; Taiwanese and Chinese fishers exchange seahorses at sea; Indonesians send them as gifts to relatives in Taiwan; and small exported volumes of under two kilograms need not be declared in Australia (Vincent, 1996).

2.6.3.3. Volume and value of global trade

The demand for seahorses, particularly larger species, far exceeded supply and the increased global consumption of seahorses appeared to be driven primarily by China's economic growth, both through direct imports and through imports via Hong Kong (Vincent, 1996). Tentative estimates arrived at by Vincent (1996) indicated an annual global trade of 20 million seahorses, which though appeared to be far from reality. The annual trade within Asia amounted to at least 45 tons of dried seahorses, which corresponds to 16 million dried seahorses, given a mean count of 350 dried seahorses per kilogram, as it was estimated by Vincent (1996). Vincent (1996) suggested that more precise calculations would clearly need to include a weighed assessment of seahorse numbers per kilogram in each country based on the volume traded by that country, and the available data were too incomplete to justify such detailed analysis.

2.7. Aquaculture of seahorses

Syngnathids, particularly seahorses have been kept in aquaria, as a favourite pet fish, for decades. It is mainly through the attention and care of aquarists that considerable knowledge exists about the culture of these extraordinary fish and to study their peculiar morphology and behaviour. Given the high commercial value, the insatiable market demand, these fish could be cultured as non-food aquatic products. Their self-sustained culture in captivity has the potential to help reduce fishing pressure on wild seahorse population while providing alternative livelihoods for seahorse fishers. Seahorse aquaculture may obviate further depletion of wild stocks, as in many species of freshwater ornamental fish. Given the appropriate technology, small scale and commercial operators may have the potential to supply the species and quantities demanded by the market, as has been the case with shrimps, prawns, tilapia and catfish (Prein, 1995).

Seahorse culturing can also be highly problematic in conservation terms, with costs to wild seahorses that far exceeds the benefits (Lourie *et al.*, 1999a). Demand for seahorses is so high that it will be virtually impossible to flood the market with cultured seahorses, especially given the general preference for wild-caught animals in traditional medicine. Moreover, seahorse fishers are generally so poor that they cannot stop catching seahorses unless they earn money in other ways. Thus seahorse aquaculture that does not involve seahorse fishers is unlikely to have many conservation benefits (Lourie *et al.*, 1999a).

The culture of marine fish is generally difficult because eggs and larvae are very small and require very specialised diets. Syngnathids, however, have relatively few, large eggs and release their young at an advance stage, which is much larger than most marine fish. Experience with seahorse larval rearing dates back to several decades. At the Wilhelma Aquarium in Stuttgart, Germany, two species of seahorses (*H. kuda* and a species from the Philippines) have been bred for generations since the early 1970s (Prein, 1995). However, because of technical difficulties, seahorse culturing has not yet been proven biologically and economically successful, in most of the culturing nations, except, the recent reports from Australia and New Zealand. Most of the earlier and persistent efforts in countries like China, Indonesia, the Philippines, South Africa, Thailand and Vietnam were largely unsuccessful (Vincent, 1996). Economic viability of seahorse farming was usually limited by low yields; most perhaps all of China's seahorse farms were closed in the aftermath of economic reforms in the 1980s unable to make sufficient profit despite their years of culturing experience.

Farming seahorses has proven technically challenging because of problems with diet and disease. Seahorses are strict predators that will essentially eat live, moving prey. Moreover, cultures must be adapted to meet different food needs as the seahorse grows. In addition, scrupulous hygiene is required to prevent these fishes from succumbing to a wide array of parasitic, fungal and bacterial ailments (Vincent, 1996). Most of the seahorse cultures rely heavily on repeated removal of wild seahorses to replenish the captive population, and need wild-caught food to supplement cultured foods. Thus, the term 'seahorse culturing' has most commonly referred only to wild-caught pregnant males giving birth in captivity or to seahorses mating in captivity with subsequent births, except the recent successes reported in Australia and New Zealand (Lourie *et al.*, 1999a).

Successful seahorse culturing must ensure that the life cycle has been closed repeatedly and reliably to be called successful, captive-bred seahorses must themselves have produced normal sized broods of healthy young for several generations. The major difficulty lies here, that the rearing of large portions of the young to maturity usually takes many months to a year. Moreover, seahorses born in captivity themselves generally produce few and small young, that fail to flourish (Lourie *et al.,* 1999a). However, the existing knowledge available on seahorse farming indicates that there is potential for the culture of high valued species such as seahorses, to satisfy the demand for them from the traditional medicine and aquarium industries. More importantly aquaculture could be used as a valuable tool to replenish impoverished national stocks.

2.7.1. Seahorse juvenile rearing

Seahorses are notoriously difficult to culture and economically farm on a large scale, and to date seahorse farming has proved technically challenging with few successes (Vincent, 1996, 1998). Long-term maintenance of large seahorses such as *H. subelongatus* in captivity is difficult (Lunn and Hall, 1998). Even more difficult is the rearing of juvenile seahorses. Most attempts to rear newborn seahorses have utilised diets consisting entirely of *Artemia* nauplii, although in many seahorse species this diet has resulted in very poor juvenile survival (Lunn and Hall, 1998).

One of the major constraints facing successful seahorse culture is the low juvenile survival rate that is often encountered in the first few months of rearing (Forteath, 2000), the reason for which is poorly understood. However, some researchers have been able to achieve high survival in the early juvenile stages. Correa *et al.* (1989) obtained a survival rate of 97% for the juveniles of *H. erectus.*

2.7.2. Captive breeding trials

2.7.2.1. China

Seahorses were actively farmed in China from the 1950s to the early 1980s (Anon, 1982, 1990b). Seven large seahorse cultures operated on the South China sea coast, two in Guangxi Province, two in western Guangdong Province, and three in eastern Guangdong Province, during the time of peak culturing activity (Vincent, 1996). Other cultures were located in Hainan Province and all along the

Southern coast. During the 1960s, seahorse culturing also involved Zhejiany, Jiangsu, and Shandong Provinces, farther north. Despite all this activity, it was reported that the seahorse farms apparently made little difference to the national seahorse supplies, and most of the farms were closed due to technical and economic reasons (Vincent, 1996). Xu (1985) discussed the development of marine fish aquaculture in China describing the major cultured species as being mullets, tilapias, milk fish, porgies, groupers and seahorses.

Aquaculture efforts ceased because of combined biological and economic difficulties. The seahorse farm at Beihai was representative of larger seahorse culturing attempts, and could obtain rearing success of 50-60% during good times, and managed to rear three to four generations in captivity. However, the project was abandoned as an economic failure in 1986 (Vincent, 1996). Another seahorse farm cultured 'black' seahorses from Shantou and Southeast Asia, and reared the seahorses for six months before harvesting. Mature seahorses were kept easily, but it took considerable effort to achieve 30% survival of young to maturity (140mm). Although this Project was classified as 'successful' (even with its poor yields) by the National Medicine and Pharmaceutical Administration, it was abandoned in 1987 (Vincent, 1996)

Based on a trial culture of seahorses Liang (1992) suggested the establishment of *Hippocampus* 'fingerling supply grounds' in China by technological consultancy services in co-operation with coastal shrimp hatcheries, so that once the artificial propagation of *Hippocampus* succeeded and popularised then its economic and social benefits would be considerable. Zhang *et al.* (1996) gave descriptions of species available, their morphology and distribution of seahorses along the Chinese coastal areas, which is an important resource for Chinese medicine. Based on ecological data, the choice of the cultivable species, the selection of farming areas, as well as farm management practices have also been analysed.

The common consensus in China was that seahorse farming just did not pay when compared to other aquaculture efforts such as food fish, shrimps, clams and pearl oysters. Culturing seahorses posed serious technical problems, although most biologists and TCM dealers felt that these could be overcome

(Vincent, 1996). Breeding seahorses was said to be relatively simple, but rearing the young was highly problematic. The young seahorses in captivity were plagued from birth with nutritional problems and disease, resulting in high mortality rates and low productivity.

2.7.2.2. Thailand

Seahorse captive rearing studies were undertaken by Bangsaen Institute of Marine Sciences (BIMS) in Thailand, for about 6 years, with the intention of reducing fishing pressure on wild populations (Chaladkid and Hruangoon, 1996; Hormchong, *et al.* undated). Pregnant males were caught from the wild, and the captive born young reared, achieving 60% survival at 90 days (about 75 mm). Second generation was not produced and breeding the adults had proven more difficult (Vincent, 1996).

Disease (mostly protozoans) presented the greatest husbandry problems. The programme was then moved to Southern Thailand in search of better water quality. Declining populations of seahorse was making it difficult for BIMS to obtain enough wild seahorses to run its culturing trials (Vincent, 1996).

2.7.2.3. The Philippines

The seahorse-culturing project initiated by the Department of Agriculture in Marunggas Island in 1988, essentially involved capturing pregnant males and rearing the young in floating cages. However, only 12% of the young survived even a week. Problems with disease and feeding were exacerbated by algal blooms, which deteriorated the water quality. This seahorse-culturing attempt was subsidiary to other cultures in the same project (for sea cucumbers, sea weeds, abalones, sea shells and groupers), which might have diminished its effectiveness (Vincent, 1996).

Fishers in Jolo sometimes used cages as fattening pens to hold adults so that they may gain weight before sale, and thus be worth more. The Bohol seahorse conservation Project also used cages only to hold captured pregnant males until they released young to the wild, prior to sale (Vincent, 1996).

2.7.2.4. Vietnam

The Institute of Oceanography had been carrying out captive breeding trials for five years, with steady improvement of results. It was aimed at developing small-scale seahorse culturing in net fish cages placed in ponds and estuaries (Vincent, 1996). Pham (1993) described the procedure for keeping the seahorse *H. kuda* in captivity in Vietnam. The behaviour of the males and females during mating and spawning were closely observed, and the growth of young monitored. It was reported that about 200-1000 larvae could develop in the male's brood pouch, which was incubated for 20-28 days. Pham *et al.* (1998) studied the embryonic and larval development of *H. kuda* in Vietnam, which would enable them to be cultured on a mass scale. Job *et al.* (2002) has also conducted detailed experiments regarding the captive culture of *H. kuda* in Vietnam.

2.7.2.5. Indonesia

The Sea farming Development Centre in Lampung, Sumatra, was actively involved in seahorse culturing, using a species in the *H. kuda* complex. It was successful to manage survival rates of unto 53% of young, by feeding them on copepods to 10 days and then on brine shrimp nauplii (Vincent, 1996).

2.7.2.6. Europe

Public aquaria in Berlin and Stuttgart in Germany were unusual in having done well at keeping seahorses. The UK Federation of Zoos Fish and Invertebrate Taxon Advisory Group (FAI-TAG) had launched a Seahorse Conservation Group, comprised largely of staff from public aquaria that kept seahorses. The goal was to improve captive breeding so as to reduce demands for wild seahorses for aquaria. A successful pilot study by a very large aquarium fish trader offered hope of supplying the UK domestic market form captive breeding, and of transferring culturing expertise to developing countries (Vincent, 1996).

2.7.2.7. Australia

Ireland (1997) reported that there were four varieties of seahorses in the Australian waters of which the best known is the Western Australian seahorse, *H. angustus*, found on reefs and seagrass meadows between Exmouth and

Australia. Lawrence (1998) carried out an investigation of the reproduction and spawning of *H. angustus* in captivity, and successfully raised a number of them.

Australia has made considerable progress in the farming of seahorses by setting up the first seahorse farm by a private company Seahorse Australia, based in Tasmania. The company has established a large scale farm for producing the large-bellied seahorse *H. abdominalis* through the use of new technology, careful selection of the species and bringing together a team of experts (Forteath, 2000). The company's initial focus was stated to be supplying to the aquarium trade, with a view to expanding into other markets, including Chinese medicine. The large-bellied seahorse, a native to Southern Australian and New Zealand waters strive in a wide temperature range, being found in waters between 9 and 27^{0}C. The species was also able to withstand remarkable salinity changes (15 to 37 ‰), which make them an ideal fish for aquaria (Forteath, 2000).

2.7.2.8. New Zealand

Gilbertson (1987) highlighted the prospects of farming of seahorses in New Zealand for the lucrative Asian Pharmaceutical market, retailed in the dried form for about NZ$ 600 kg^{-1}. The first attempt to culture seahorses in New Zealand near Nelson, during the mid 1980s, failed because of husbandry problems (Vincent, 1996). Trial culture of big bellied seahorses *H. abdominalis* began in New Zealand in 1993, by an aquaculture company on the North Island, presumably operating under a research permit since land-based seahorse culture was illegal (Vincent, 1996). About 400 seahorses were held as brood stock, aimed eventually to supply seahorses to the USA. It was however, reported to have suffered from high juvenile mortality. Anon (1997) reported the first seahorse farm to be set up in New Zealand's Marlborough Sounds, which could become one of the biggest export earners for the marine shrimp farming industry. It was recommended that clinical trials needed to be done to establish the effectiveness of seahorses for medicinal purposes, for a possible domestic market in New Zealand, as being widely practiced in oriented medicine. This was followed by a second company, which investigated the potential for seahorse culturing in 1995. The biologists at the University of Auckland and the University of Otago were also involved in seahorse culturing in 1995 (Vincent, 1996).

Anon (1998) reported attempts to culture the big-bellied seahorses *H. abdominalis* in cages in New Zealand as a means to overcome the heavy fishing effort, which dramatically affected their wild populations. In New Zealand, some seahorses were also incidentally cultured in abalone farming operations, because the fishes helped to reduce plankton in the water. The seahorses were not considered a product thèmselves in such instances (Vincent, 1996).

2.7.2.9. South Africa

Kaiser *et al.*(1997) suggested that there existed an opportunity for South Africa to develop ornamental fish farming sector. The breeding and larval rearing techniques for the Knysna seahorses, *H. capensis,* pipe fishes and a number of damsel fish species were being developed. Kaiser *et al.*(1997) noted that the temperate South African climate necessitated that fish from tropical areas were cultured either indoors or in plastic covered horticultural tunnels, and research was underway at Rhodes University to develop intensive culture techniques for both freshwater and marine ornamental fish.

Lockyear *et al.* (1997) attempted the captive breeding of *H. capensis* at the Rhodes University in South Africa, during the non-breeding season (winter), using photo-thermal manipulation. All the combinations tested namely 20L: 4D and 20^{0}C; 16L:8D and 25^{0}C; and 12L:12D and 28^{0}C were successful in extending the breeding season of *H. capensis.* The different photoperiod-temperature combinations did not affect the frequency of pregnancies as well as the number of young produced per pregnancy. Lockyear *et al.* (2000) observed that the seahorse pairs exposed to medium light intensity produced more broods than those pairs maintained under low and high light intensities.

3. MATERIAL & METHODS

3. MATERIAL & METHODS

3.1. Seahorse resource survey

An organised fishery for seahorses exists only in the southern coast of Tamil Nadu. A resource survey to assess the landing of seahorses along that coast was conducted, especially at the landing centres in Palk Bay and Gulf of Mannar. Periodic random sampling was done at Thondi, which is the major fishing area for seahorses in Palk Bay. Seahorse fishing at Thondi was carried out by raw divers who set out to the sea in small groups of 6 to 8 numbers in country boats, and by fishermen in small motorised country crafts using *thallu vala*, which is a mini trawl type net dragging along the bottom of the sea. During the year 2001, monthly landing data of seahorses from five country boats were collected sex wise, in random for five consecutive days and the mean daily landing was calculated. The total number of boats that were in operation on the five days of observation was noted and then the mean number of boats fishing on each day of that month determined. The total number of seahorses caught in each month was then computed by multiplying the mean daily catch with the mean number of boats operating daily and the total number of days of fishing. The total male and female seahorses landed on each month was also noted. The annual landing of seahorses for the year 2001 was calculated by adding the catches obtained for the 12 months from January to December 2001.

Fishing in this region was restricted to 6 days in a week, with the motorised and non-motorised crafts engaged in fishing on alternate days. Based on this and the actual observations, the total number of days of fishing was assigned for every month. However, there was apparently no significant difference in the quantum of the seahorses caught in either type of these crafts and therefore they were treated as identical while sampling. Fishing was almost continuous round the year except the seasons when the sea was too rough to go. Since fishing was the mainstay of their livelihood, fishing was done even during the festival seasons with the fishermen managing with other members of their group.

The data were collected on any five days falling between the 10th and 20th of every month, for 12 months from January to December at Thondi. Interviews with the two major wholesale buyers of seahorses in Chennai, and several other local middlemen were relied upon in order to understand the percentage share of Thondi in the total landings of seahorses from Palk Bay and Gulf of Mannar. Based on that, the total landing at Thondi was fixed as 68% of the total landing from Palk Bay, and Palk Bay in turn contributed 76% of the total landing from the southern coast of India. Based on those assumptions the total landing of seahorses in India was calculated.

Occasional samples were also gathered from all the important landing centres to understand the species composition of those areas. Though there was no organised fishery in Kerala, the landing at Sakthikulangara/Neendakara harbour was estimated. Regular samples were collected on two days in the first week and third week of each month for one year (2001) maintaining an interval of 13 to 16 days between two data collections. The data was collected from the boats systematically in the order of their landing. The landing data was collected sex wise, and the mean number of male and female seahorses obtained from 10 boats on each day was computed. Then based on the mean number of boats that were in operation on each of these days and the number of days of operation, the total landing of that month was computed. The total catch for the year 2001 was then calculated by adding the catches obtained for the 12 months from January to December 2001. Also the sex ratio of the catch was determined month wise.

3.2. Taxonomy

The seahorse specimens collected from Thondi were dried and taken to the laboratory for identification of species, using morphometric characters, and the meristic counts as described by Lourie *et al.* (1999a). Specimens from the other areas ware also collected through agents. These were then segregated source wise, and the species identified based on the detailed key and seahorse measurement protocol provided by Lourie *et al.* (1999a). The identified species were listed against their source of collection, and the percentage abundance of these species in the respective landing centres was determined. Morphometric measurements were taken using vernier calipers, to the nearest 0.1mm, on the right side of the seahorses, and repeated to ensure accuracy. Fin rays and tail rings (at the distal end) were counted under a dissection microscope.

3.3. Length-weight relationship

Because of the ecological and economic importance of seahorses, the data on their functional length-weight relationship is important for fish stock assessment. The parameters 'a' and 'b' of the length-weight relationship ($W = a L^b$) can be used for length-weight conversion as well as to estimate the relative condition factor. Data on standard length in mm, and body weight in g were recorded for each seahorse in a sample of *H. kuda*. The standard length was measured as the distance from the tip of the snout to the mid point of the opercular ridge, and then at right angles down to the tip of the tail when extended as described by Lourie *et al.* (1999a). The parameters 'a' and 'b' of the length-weight relationship of the specimens of *H. kuda* were estimated using logarithmic transformation of the equation $W = a L^b$ (Sparre *et al.*, 1989) and the condition factor Kn was calculated.

3.4. Length Frequency analysis

The data on total length of the seahorses collected from Thondi were classified into different size classes and the frequency were plotted against the respective classes, specieswise, in order to understand the dominant size of the catch composition for each species. The length frequency data of *H. kuda* based on bimonthly collections were used for studying its growth pattern. The data were analysed using the FiSAT II programme (Gayanilo *et al.*, 2002). From the modal progression plot for analysis of the mixtures of distributions (Bhattacharya Method), the average length at every bimonthly sample was evaluated, which gave an age-length relationship (age being taken as equivalent to two months' period). From this, the VBGF plot was obtained which gave the values for $L\alpha$ and K. The parameters obtained were used as input to length-converted catch curves to obtain estimates of total mortality (Z), following Pauly (1983). Natural mortality (M) was estimated using the empirical formula of Pauly (1980), with T set at 30^0C. Fishing mortality (F) was estimated from $Z = F + M$ and the exploitation rate (E) was obtained from $E = F / Z$. The probability of capture curve was also plotted by backward extrapolation of the length-converted catch curve for comparison of the numbers of seahorses actually caught with those that ought to have been caught, using the logistic curve, assuming the selection to be symmetrical or nearly so.

3.5. Gut content analysis

Gut content analysis was done for adult *H. kuda* collected from Thondi ranging in size from 10-11.5cm wet length and 5.8 - 7.4g wet weight. The seahorses (n=20) were killed by immersing in 10% formalin (within 2 hours of capture). The seahorse abdomen was then opened with a ventral incision along the keel line and the digestive tract removed and fixed in 10% formalin. The lengthwise incision along the gut was made and the contents flushed out into a gridded (1x1mm grid) counting tray. These were viewed under a binocular microscope and the contents analysed.

3.6. Breeding Biology

3.6.1. Size at first maturity and breeding season

The condition factor Kn computed from the length-weight relationship was plotted against the length of males and females of *H. kuda* collected from Thondi. The length corresponding to the first peaked Kn was assumed to be the size at first maturity. The average Kn was also determined for males and females monthwise, and then plotted against the months so as to determine the breeding season of *H. kuda* at Thondi.

3.6.2. Fecundity and ova diameter

Fecundity of the female was estimated by cutting open the female with bulged trunk, obtained from the catch of the fishermen. Since the size of ovary was small, the entire ova in the ovary were counted and the number of ova per gram body weight of the female was computed. Ova diameter was measured in the longitudinal axis, using a calibrated stage micrometer.

3.6.3. Breeding behaviour and courtship

Captive broodstock of seahorses was maintained in a glass aquarium of 150 litre capacity (60x60x45cm) provided with an under-gravel filter made of crushed coral and shell sand, and the tank filled to the maximum capacity with clear seawater of 33 ± 1 ‰, filtered through a 5 μ filter bag. Five adult males and 5 females (of mean size 10.5 ± 1.2 cm and 6.9 ± 0.95 g) were stocked in the tank for conditioning. Untwisted strands of a polypropylene rope, weighted to the bottom by tying to coral pieces were used as holdfast to the seahorses. Some plastic artificial plants were also kept in the tank for the seahorses for anchorage. No aeration stone was kept, since the under-gravel filter was functioning continuously. A photoperiod of 12h-L and 12h-D was used from two 40W fluorescent tube lights fixed above each tank.

The courtship behaviour of the seahorses conditioned in the tank were closely watched regularly to study the behavioural changes and to isolate the paired ones. Individuals that displayed courtship behaviour were separated early morning to a breeding tank of 180 litre capacity (45x45x90cm) and observed for mating. A deeper tank was used in this study to allow vertical space for courtship and mating of the pairs. Artificial aquarium plants and polypropylene ropes weighted at the bottom were kept in the tank as holdfast. If mating did not occur within 5 days between this pair, they were returned to the conditioning tank and another couple was selected based on daily greetings and courtship behaviour. The breeding and courtship rituals of the brood seahorses were videographed and the various phases of courtship behaviour of males and females that culminated in mating and egg transfer were analysed. Still photographs were taken from the videotape.

After mating and egg transfer, the couple were transferred to a hatching tank of about 70 litre capacity (60x45x30 cm) for incubation and hatching. The male and female were kept together in this tank until the male released the hatchlings. After delivery, the male and female were transferred back to the breeding tanks, filled with filtered, fresh seawater. If remating did not occur within 5 days, the pair was returned to the conditioning tank.

3.6.4. Broodstock rearing

The brood seahorses kept in conditioning tanks, were fed adult *Artemia* (brine shrimp), 3-10mm size cultured in 80 litre buckets in a mixed micro-algal medium dominated by *Chlorella* sp. Yeast was also added occasionally in small quantities to the algal tanks, in addition to low doses of fertilizers, urea and super phosphate. Seven such tanks were maintained under diffused sunlight to supplement feed to the *Artemia*. Vigorous aeration was provided to the culture containers. About 2g of *Artemia* cysts (Great Salt lake strain; INVE Thailand brand) were weighed and incubated in these tanks for hatching. The cysts hatched within 24 hours, and after complete hatching, the debris and unhatched cysts were removed from the bottom by siphoning, done after stopping aeration for 30 minutes. The *Artemia* nauplii reached maturity within 2 weeks, and the culture became self-sustained. However, every week 0.5g cysts were also added to the tank. The tanks were topped off regularly with freshwater to make up for evaporation loss and about 25% of culture water was replaced every week. Each seahorse in the conditioning tank was given at least 250 adult *Artemia* per day as feed.

Occasionally the seahorses were also fed with tiny freshwater prawns that usually occurred during rainy days in swamps and paddy fields. They were collected in the morning as and when they were available. Collection of these prawns was possible three to four days, every week during the experimental period. The prawns were kept in buckets with freshwater under moderate aeration. If they were intended to be kept for more than one day, they were fed with *Artemia* nauplii. These prawns survived in seawater for more than half an hour, within which period the seahorses would eat them.

In addition, mysids collected from a brackish water pond were also held in buckets with aeration. However, it was not possible to hold mysids for long since they suffered heavy mortality on storage for more than two days, and therefore fresh collection was resorted to regularly.

Along with mysids, some tiny fry of fish were obtained, and were tried as feed for adult seahorses, which they ate voraciously. These were kept in buckets with aeration and were fed to the seahorses at 10 numbers per each seahorse, three times daily. The fry, which soon increased in size in the holding buckets were discarded, and only those that were sufficiently small to become a mouthful were selected and fed to seahorses.

3.6.5. Hatching

The pregnant males obtained from the wild were transferred and maintained in different salinities of 5 to 50 ‰ with an interval of 5 ‰, after gradual acclimatisation. The time of hatching and the percentage of hatching in each salinity was noted. The size of the hatchlings were measured in length and weight soon after hatching. The hatchling was stretched on a scale and the length from tip of snout to the tail was noted. The weight was measured using Shimadzu electronic balance with a precision of 0.01 mg.

3.7. Juvenile rearing

The success of the larval rearing and production of juveniles greatly depends on the identification of proper feed, optimum conditions for the larvae like stocking density, lighting, and the tolerance to various physico-chemical parameters, and therapeutic chemicals (which are used for treating various infections or against pathogens). In the present study, an attempt was made to standardize the larval rearing technology of seahorse, *H. kuda* by determining the optimum parameters for the best growth and survival of the juveniles. With this in view five experiments were carried out.

i) to determine the efficacy of different feed combinations as an appropriate diet in the captive rearing of the juveniles of *H. kuda*, that will ensure the highest survival and growth;

ii) to find out the optimum stocking density of the hatchlings of *H. kuda* appropriate for captive rearing;

iii) to determine the optimum salinity of water suitable for captive rearing of the juveniles of *H. kuda;*

iv) to determine the effect of light in improving the early juvenile survival of *H. kuda* under captive rearing; and

v) to study the tolerance of juveniles of *H. kuda* to extreme salinities, and pH of water, and to one of the most common therapeutic chemicals used in aquaculture, viz. formalin.

All the rearing trials were completed within a span of 4 months (July to October) and the fluctuations in water quality parameters were kept minimum. The important water quality parameters in the experimental tanks such as temperature, salinity, pH, ammonia, and dissolved oxygen were monitored daily in all the trials.

The salinity was measured using a salino-refractometer (ATAGO, Japan), temperature using a mercury thermometer, and the other parameters using Hach test kits (USA).

3.7.1. Determination of the optimum diet

Hatchlings obtained from wild, pregnant males of *H. kuda* were used for the studies on larval rearing. The hatchlings obtained from two pregnant males were mixed together and 300 hatchlings were then randomly allotted to 12 experimental rectangular glass tanks (60x30x30cm) with filtered clean seawater filled to a height of 25cm to have an effective volume of 45 litres. Three feeding regimes for the hatchlings were tested using 4 replicates for each treatment (25 hatchlings in each tank). Mild continuous aeration was given using aquarium aerators. Air from the aerator was channelled through a 3mm dia P.V.C. tube and diffused in the water with the help of a 1" dia and 2" long hard airstone. Untwisted strands of a polypropylene rope, weighted at the bottom using a hard piece of coral stone were provided as hold fast to the growing seahorse fry. The feeds tested were freshly hatched and enriched *Artemia* nauplii, mixed marine copepods and freeze-dried Cyclop-eeze (Argent Laboratories, USA).

In the first treatment (T_1), enriched *Artemia* nauplii alone was fed to the hatchlings, in the second treatment (T_2), enriched *Artemia* nauplii + copepods, and in the third treatment (T_3), enriched *Artemia* nauplii + freeze-dried Cyclop-eeze were given. During the first seven days all the tanks were fed with freshly hatched *Artemia* nauplii alone, and then switching over to different combinations using enriched *Artemia* nauplii. Feeding started on the day of stocking of the hatchlings, twice daily at 7 hours and 16 hours during the first week. From second week onwards, feeding was split into three times at 6 hours, 12 hours, 18 hours daily, with enriched *Artemia* nauplii were given at 12 hours and the rest two feedings of copepods or Cyclop-eeze.

Before the experiment, the quantity of each feed to be given to the hatchlings was standardized by an observational trial for 2 days, to determine the feed affinity and predation rate of each feed by the hatchlings. Five hatchlings (10 days old) were taken in a 500 ml glass container with fresh seawater. Freshly hatched *Artemia* nauplii were counted and presented to the animal by a dropper beginning with 20 numbers. The predation over 10 minutes was carefully watched and the count projected to the predation rate $hour^{-1}$ for each feed. Since the predation rate of freeze dried Cyclop-eeze was low, the trial feeding was observed for one hour and the rate determined. In the case of copepods, it was difficult to measure predation rate, and therefore it was fed to the hatchlings *ad libitum*.

Artemia cysts (INVE Thailand brand), which gave a nauplii count of 1,60,000 g^{-1}, were used. Hatching of the cysts was done under standard conditions, in 100 litre transparent plastic buckets, with brackish water of 25 ‰ salinity and 29±1^{0}C under vigorous aeration. The hatched out brine shrimp nauplii (BSN) were separated from the unhatched cysts and broken shells by repeated siphoning. The BSN were collected in 10 μ mesh size nylon bolted silk, washed thoroughly in running sea water from a tap for 2 minutes to remove debris, and the broken and dissolved shells attached to the nauplii. This clean BSN were fed to the hatchlings. The nauplii count was estimated volumetrically three times from the same batch and the mean count estimated. Based on the nauplii count of 1,60,000 g^{-1} cysts, the initial quantity of BSN to begin feeding was fixed as 2 g for 300 hatchlings. This was later increased based on demand.

The *Artemia* nauplii harvested from the hatching tanks were enriched using Super Selco (INVE Thailand), which is a ready-to-use substitute for cod liver oil, and is a commercially available *Artemia* enrichment medium. As per the recommended procedure, the *Artemia* nauplii, after harvesting were stocked in 50 litre transparent buckets at a density of 150 - 200 ml^{-1} and were enriched with Super Selco at the rate of 600 mg l^{-1} and incubated for 16 h under heavy aeration, at room temperature. This was added to the enrichment buckets in two doses of 300 mg l^{-1} each, first at the beginning, and then after 10 h. After 16 h of enrichment, the nauplii were harvested and fed to the seahorse fry.

Cyclop-eeze, a commercial larval feed (Argent Laboratories, USA) is a copepod organism cultured in a pristine Arctic lake north of Canada and is reported to contain one of the highest levels of the carotenoid pigment, astaxanthin and essential fatty acids. Lieberman (2001) reported that the Cyclop-eeze contains about 3000 to 7500 ppm of astaxanthin and exceptionally high levels of highly unsaturated fatty acids (HUFAs), and it is being used widely as a substitute for the live feed *Artemia* in the larval rearing of many marine finfish and shellfish. Cyclop-eeze was reported to contain 17,000-18,000 organisms g^{-1} and the size measured about 800 µ, which is almost 60% bigger than that of the freshly hatched *Artemia* nauplii (420 – 530 µ). The predation rate was found to be 7 Cyclop-eeze h^{-1}. Therefore 1 g Cyclop-eeze was fixed to begin with, for feeding 300 seahorse hatchlings per day, and later the quantity adjusted based on demand.

Marine copepods were collected from the seawater storage tanks and high saline brackish water ponds by fine mesh nets of 1000, 500 and 250 µ size in that order. The seawater was stored for a few days to allow copepods of different species to develop. They were collected at night from the water surface, making use of the phototactic movements. The copepods were collected first using a 1000 µ mesh to remove any debris and then passed through a 500 µ mesh to filter out bigger individuals and any undesirable organisms like jelly fish larvae, and finally collected on a 250 µ mesh. Imported bolted net were used in all these stages. The collected copepods were kept in 5 litre plastic basins in the same water (filtered through a 5 µ filter cloth bag) taken from the copepod tank, and kept aerated until feeding to the seahorse fry the next day morning. The debris and other unwanted materials, if any were removed by siphoning, and the copepods were siphoned off from the surface for feeding the hatchlings.

It was ensured that the feed remained in the treatment tanks all the time. Feeds were provided *ad libitum* and the feeding rates were adjusted such that the hatchlings finished almost all the feed by the next meal. Any uneaten feed remaining in the tank was removed before each feeding. After the morning feed, the remaining quantity of the freshly hatched *Artemia* nauplii were taken in a 2 litre dark coloured plastic basin with fresh brackish water of 25 ‰ and kept in a refrigerator, so that it remained viable without growth, until the next feeding. Any excess nauplii after the whole day's feeding were stocked in the adult *Artemia* culture tanks.

The survival of the hatchlings were noted daily, and the dead ones removed from the tank, and the bottom cleaned by siphoning followed by 50% exchange of water. During water exchange, half of the water was removed from each tank and it was replaced with fresh seawater. The water quality parameters like temperature, pH, salinity, dissolved oxygen and ammonia were monitored in each tank daily.

The hatchlings were reared for a period of 60 days using the three feed treatments. The survival of the hatchlings was noted after 7^{th}, 14^{th}, 21^{st}, 28^{th} and 60^{th} day of rearing and the length and weight measurements were taken just after hatching and after 7^{th}, 14^{th}, 28^{th} and 60^{th} days of rearing. Length was measured by stretching the larvae over a scale from tip of mouth to the end of tail. Weight measurements were taken using a Shimadzu electronic weighing balance with a precision of 0.01 mg. For weighing, the hatchlings were taken out of water using forceps, and were placed in a tissue paper to mop them dry, and weighing was done as quickly as possible to have least stress, and avoid suffocation. Five specimens from each tank were used for length and weight measurements, and the means estimated.

At the end of 60 days, the rearing experiment was stopped and the number of hatchlings survived was noted, and the percentage survival for each replicate tank under each treatment was computed. The percentage growth was then computed as $[(W_2-W_1)/ W_2] \times 100$, using weight measurements where W_1 = initial weight and W_2 = final weight. The specific growth rate (SGR) which represents the average percentage increase in body weight per day of the hatchling over the experimental period was calculated as $[(\log_e W_2 - \log_e W_1)/t_2-t_1) \times 100$.

The experiment was analysed using completely randomised design (CRD) with 4 replications for each treatment, and the results subjected to analysis of variance (ANOVA) (Snedecor and Cochran, 1967). Pair wise comparison by 't' test was used to find out the optimum feed combination that ensured maximum survival and growth.

3.7.2. Determination of optimum stocking density

The experiment for the determination of optimum stocking density of the hatchlings of *H. kuda* under captive rearing was done in rectangular, aquarium glass tanks of size 60x30x30cm filled to a height of 25 cm, so as to get an effective volume of 45 litres. Six treatments of stocking density namely 1 L^{-1}, 2 L^{-1}, 3 L^{-1}, 4 L^{-1}, 5 L^{-1} and 6 L^{-1}were tested with three replications for each treatment. A total of 945 hatchlings obtained from three pregnant males collected from the wild were used for the study.

The hatchlings were fed with newly hatched nauplii of the brine shrimp for the first 7 days twice daily at 7 hours and 16 hours, and then weaned to a diet given thrice daily, consisting of marine copepods fed at 7 hours and 18 hours, and enriched *Artemia* at 12 hours. Continuous, mild aeration was provided to the tanks, using aquarium aerators, channelled through 3 mm P.V.C tubing, and diffused in the water by 1"x2" air stones. Untwisted strands of a polypropylene rope weighted at the tank bottom served for the attachment of seahorse fry. About 50% of the water in each tank was replaced daily in the evening before feeding, after removing any faeces or waste from the tank bottom. Any dead pieces from the tank were noted and removed. The rearing was continued up to 60 days.

The juveniles obtained from each tank at the end of 60 days were counted, and the mean length and weight measurements of 10 juveniles from each tank taken. The percentage survival, and the production of juveniles per litre for each treatment of stocking density were calculated. The increment in length and weight of the juveniles were also noted. The results obtained were statistically analysed using one-way analysis of variance, and wherever the differences showed significance, pair wise comparison using Students 't' test was done to determine the optimum stocking density. Since the value for production per litre obtained was a small figure, it was transformed using the equation, $\sqrt{y+0.5}$ where y is the value of production per litre obtained (Rangaswamy, 1995).

3.7.3. Effect of salinity on juvenile rearing

The experiment to determine the optimum salinity of water at which the rearing of the juveniles of *H. kuda* could be carried out was conducted in rectangular aquarium glass tanks of size 60x30x30cm, filled with water to a height of 25 cm (45 litres). A stocking density of 2 juveniles L^{-1} (90 numbers/tank) was used in all the tanks. Freshly hatched larvae with an initial average length of 0.7 cm and weight 0.00186 g were used for the experiments. The experiments were conducted for a period of 14 days. Seven salinity levels of 5 ‰, 10 ‰, 15 ‰, 20 ‰, 25 ‰, 30 ‰ and 35 ‰ were tested to determine the optimum salinity of rearing the juveniles. Continuous mild aeration was provided in all the tanks. The feeding was done with newly hatched *Artemia* nauplii during the first week and later with marine copepods and enriched Ar*temia* nauplii. After rearing for 14 days, the mean percentage survival was noted, and the mean length and weight of 5 juveniles from each replicate tank were measured. The percentage survival and the growth in length in weight obtained under different salinity conditions were analysed using one-way ANOVA. Student's 't' test was used to determine the best salinity.

3.7.4. Effect of light to improve early juvenile survival

Early hatchlings of seahorse *H. kuda* were seen to have a peculiar problem of entrapping air bubbles, leading to death while trying to feed from the water surface. The major live feeds for the seahorse viz. *Artemia* nauplii and copepods, are highly phototactic, and normally congregate at the water surface, especially near to the walls of the container. Since the seahorses have a unique feeding habit of sucking in the prey in a sudden and strong inhalant current, it usually results in ingesting air bubbles while feeding at the water surface leading to buoyancy problems, and the seahorses that float on water surface often die. This is one of the main factors affecting the initial survival of seahorse hatchlings.

Three treatments were tested in the experiment with 5 replicates for each, and was conducted in aquarium glass tanks of 30x30x30cm size filled to a capacity of 20 litres. The tanks were kept open in diffused sunlight inside an area roofed with transparent FRP sheets, and the tanks under the first treatment were left uncovered. The set of tanks in second treatment, were covered with a black plastic sheet, from top of the tank up to 10 cm down from the water mark, leaving a gap of about 10 cm from the bottom of the tank uncovered so as to get 'illuminated' from the diffused sunlight in the room. In the third treatment, the set of tanks were totally covered with black plastic sheet throughout the rearing period so as to cut off any light into the experimental rearing tank.

A stocking density of 2 L^{-1} of seahorse hatchlings was used in all the tanks, and 40 hatchlings were randomly placed in each tank and a total of 600 hatchlings from two males were used in this experiment. The rearing in this experiment was done for 14 days. During the first 7 days freshly hatched *Artemia* nauplii alone was given twice daily at 7 hours and 16 hours, which was later shifted to enriched *Artemia* nauplii once and mixed copepods twice daily, for the remaining 7 days. Weighted strands of an untwisted polypropylene rope were provided at the bottom of each tank as hold fast to the hatchlings. Continuous mild aeration from aquarium air pumps diffused through 1"x1 1/4" air stone was provided in each tank.

At the end of 14 days of rearing the survived juveniles were counted and the mean length and weight of 5 individuals measured from each tank. The percentage survival was calculated and the results analysed using one way analysis of variance. Pair wise comparison using Students 't' test was also done to determine the best treatment.

3.7.5. Tolerance studies

The experiment was carried out to study the tolerance of different levels of salinity, pH and formalin to the 2 weeks old juveniles of *H. kuda* captive reared using *Artemia* nauplii and copepods. The incipient LC_{50}, i.e., the concentration at which 50% of the larvae died after 12, 24, 48 and 72 h were computed.

Initially, trial experiments to find out the range of tolerance were conducted. It was observed that the hatchlings immediately transferred to freshwater and water more than 75 ‰ died within 8 hours. Also, when the juveniles were transferred to pH of 3 and 12, complete mortality resulted. In the case of formalin, the lethal concentration was found to be near to 500 ppm. Based on this, the levels of salinity, pH and formalin were tested for the experiment.

The test solutions were prepared by dissolving requisite amounts of analytical grade formalin for formalin test solution, hydrochloric acid (HCl) or calcium carbonate ($CaCO_3$) solution for pH and the sea salt mixture, Instant Ocean in distilled water for salinity. The experiments were conducted in 1000ml capacity glass beakers containing 900 ml of the test solution. Ten 2 weeks old juveniles were randomly allocated to each beaker, kept in 3 replications. Each beaker was provided with mild aeration from aquarium air pumps through 3mm dia PVC air tubes closed at the end and provided with two pinhole perforations at the distal end, which was kept immersed in water. The formalin beakers were more vigorously aerated. The juveniles in each beaker were fed with freshly hatched *Artemia* nauplii alone, *ad libitum,* three times a day. The test solutions in the experimental tanks were renewed once every 12 hours. All the experiments were done in room temperature. The behaviour and any external changes in the body of the seahorse juveniles were observed.

In the case of salinity, lowest levels of 0, 1, 2, 3, 4 and 5 ‰, and upper levels of 45, 50, 55, 60, 65 and 70 ‰ were tested. pH levels of 4, 4.5, 5, 5.5 and 6 and 10, 10.5, 11, and 11.5 were tested to determine the lower and upper tolerance limits for *H. kuda*. In the case of formalin, the levels of 250, 300, 350, 400, and 450 ppm were tested to study the tolerance. Formalin test solution was prepared by dissolving calculated quantities of formalin in filtered seawater at the rate of 0.02ml per 20 litre to get 1 ppm. Salinity was measured using a calibrated salino-refractometer (ATAGO, Japan) with temperature compensation and pH by a sensitive Hach pH meter.

The mortality was assessed at 12, 24, 48 and 72 h after introduction of the juveniles. The larvae that did not respond to prodding were considered as dead. The LC_{50} values for different parameters were calculated by Probit analysis (Finney, 1971).

4. RESULTS

4. RESULTS

4.1. Seahorse resource survey at Palk Bay

A target fishery for seahorses in India exists only in the Southeast coast especially along the Palk Bay where the seahorses were collected by specific divers, who target them along with sea cucumbers and chanks. In rest of the areas including Kerala, most of the seahorse collection came as a by-catch of the shrimp trawling. The major fishing centres along the South Tamil Nadu coast are located in the Palk Bay and Gulf of Mannar coasts (Fig.1).

In the Palk Bay, the fishing was mainly carried out by raw divers, using small country boats. Another type of small motorised country crafts using a mini trawl net, locally called thallu *valai* were also in operation which landed seahorses among other fishes. The quantity of seahorses landed by those two types of crafts were more or less the same, and the fishing was done on alternate days. Thus in the survey both types of crafts were treated together and data were collected from the boats on all the five days of observation, irrespective of them being country boats with divers, or *thallu valai*. In the Gulf of Mannar, a majority of the catch came from shrimp trawlers who obtained seahorses as a by-catch. The landing of seahorses was more abundant from the Palk Bay region, and the season varied according to the weather conditions. When the sea was rough, it was difficult for the divers to go for fishing and during this time the catch mainly depends on the by-catch from trawlers.

The organized fishery of seahorses in India is restricted to the Southern coast of Tamil Nadu, which accounts for almost the total trade of dried seahorses from India. There are nine major fishing areas along the northern coast viz. Thondi, Nambuthalai, Soliakudi, Pudupattinam, Mullimunai, Karangadu, Morepanai, Tirupalaikudi and Devipattinam (Fig. 1). In the Southern region also there were mainly nine centres viz. Vallinokkam, Periyapattinam, Vethalai, Kodikarai, Kottaipattinam, Mallupattinam, Vedaranyam, Earwady and Kilakarai. Thondi is the major centre on the north and Kilakarai on the south.

The divers set out to the sea in small country boats mainly to collect, seahorses, sea cucumbers and gastropods such as *Murex, Xancus pyrum* etc.

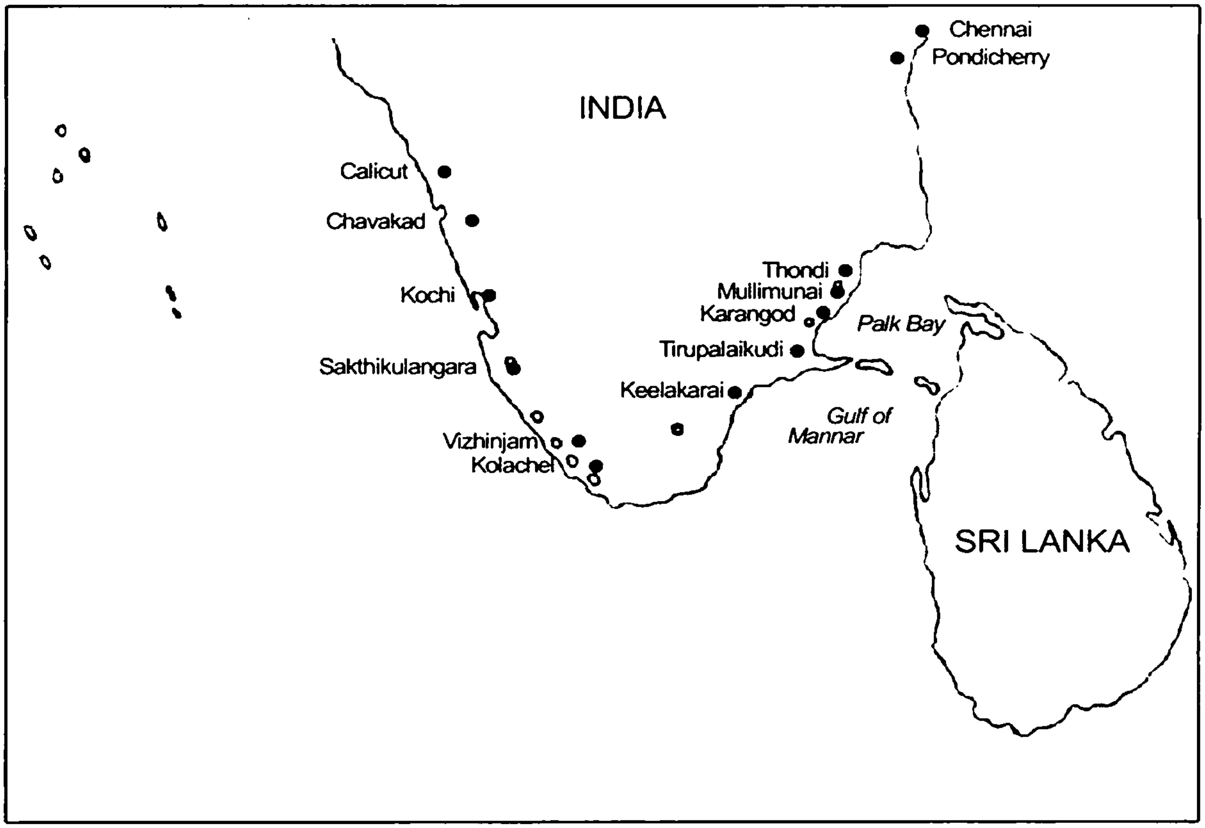


Fig 1. Map of the southern coast of India depicting the areas of seahorse availability

They dive to shallow depths of 3-3.5 m or sometimes even up to 10 to 13 metres. About 700 country boats were in operation along both the coasts. Not all fishermen owned the boat. Fishing was managed by small co-operatives consisting of 5-7 fishermen, who shared the profit. A detailed survey was conducted at Thondi, the major fishing centre in Palk Bay, to estimate the annual landing of seahorses at Thondi and the results are provided in Table 1.

The total landing of seahorses at Thondi, the major fishing centre at Palk Bay which accounted for about 68% of the landing from Palk Bay was estimated to be 13,68,579 numbers. The mean wet length and weight of the landed seahorses (assorted species) were obtained as 11.5±2.36cm and 6.89±2.041g respectively. Thus, the total landings from Thondi were estimated as 9.43 MT of seahorses per annum. The major fishery occurred from May to October, with peak in the month of August, and the lean fishery during November to April. There was a steep decline in catch in September (57, 408 numbers), compared to that of August (4,73,899 numbers).

Given that 68% of the total landings of Palk Bay came from Thondi (based on market survey), the total catch of seahorses in Palk Bay was estimated as 13.867 MT (20,12,616 numbers). It was also assumed that 76% of the total landing from the South Tamil Nadu coast came from Palk Bay. Therefore, the total annual catch of seahorses from the Gulf of Mannar and Palk Bay were estimated as 18.246 MT or 26,48,179 numbers. The trade of seahorses exclusively takes place in the dried form, except a negligible quantity that was sold live for the aquarium trade. Marichamy *et al.* (1993) had reported a yield of 53.45% when the seahorses were dried for export. Therefore, the total seahorses that were being exploited for trade was estimated to be 9.75 MT from the South Tamil Nadu coast, during 2001. The collection of big sized seahorses from Kolachel area, was totally purchased by the wholesale dealer at Kilakarai, and would thus be included in the Gulf of Mannar production.

4.1.1. Other Centres in Tamil Nadu

Seahorses were also available from areas near Tuticorin, Kolachel, Chennai and Pondicherry. The Kolachal region near Kanyakumari was said to be a

Table 1. The mean catch per boat, and the total number of seahorses caught from Thondi during the year 2001

Months	Mean catch (nos.) of 5 boats / day					Mean catch / boat	Mean no. of fisher-men in each boat	Catch/ fisherman/ boat / day	Total days of fishing	Total no. of boats/ day	Total number of seahorses caught
	Day I	Day II	Day III	Day IV	Day V						
January	13.0	11.2	6.2	17.4	24.2	14.4	5.8	2.48	27	31	12,053
February	18.2	6.8	38.8	34.2	45.8	28.8	5	5.75	24	′29	20,017
March	21.0	15.8	37.2	16.0	18.0	21.6	4.6	4.70	19	24	9,850
April	13.4	24.6	12.8	18.4	16.8	17.2	6.2	2.77	24	19	7,843
May	39.2	45.4	53.2	47.0	31.0	43.2	7.8	5.53	27	26	30,298
June	227.4	263.0	241.0	216.2	276.2	244.8	8	30.60	25	41	250,879
July	280.0	295.0	263.8	358.6	223.2	284.1	8	35.5	27	56	429,589
August	343.6	315.2	323.8	334.6	310.2	325.5	7.8	41.73	26	56	473,899
September	58.4	40.2	61.8	24.4	55.2	48.0	6.2	7.74	26	46	57,408
October	65.2	52.6	42.0	76.0	28.2	52.8	5.6	9.43	27	42	59,875
November	16.0	25.2	28.2	17.4	22.0	21.8	4.8	5.99	17	15	5,549
December	14.0	21.8	9.6	26.8	32.6	21.0	6.4	4.88	20	27	11,318
Total annual landing											**1,368,579**

major centre for big sized seahorses of 13 to 18 cm size. A minor quantity of seahorses was also available from Cuddallore area near Pondichery. The main landing centre near Chennai, Kassimedu had occasional landings of seahorses in the shrimp trawl by-catch. However, no seahorse was seen to be sorted and collected from the by-catch of trawlers from Kassimedu, during any of the five visits to that centre, though a few *H. trimaculatus* were obtained from the trawl by-catch. Seahorses were not commonly available, and they were not paid much attention, because of very small quantities landed.

4.1.2. Seahorse landings in Kerala

In Kerala, most of the small quantities of seahorses landed came from Sakthikulangara/Neendakara, and Vizhinjam harbours. There was no organized fishery for seahorses in any of the fish landing centres in Kerala. The stray catch obtained from country boats and gillnets, or ring seines, as well as the by-catch from shrimp trawlers were the main source of landings. The shrimp by-catch in many places, often went unnoticed and was dried along with Squilla, other trash fish and small crabs, and used as manure.

In the Neendakara/Sakthikulangara area, seahorses were frequently brought by the shrimp trawlers. During the months of October and November, the quantities landed were significantly high in the trawl by catch (Table 2). This season that coincided with the northeastern monsoon rains could be said to be the peak season of availability. The number of trawlers in operation at this harbour, varied from 915 to 2580 per day, and the quantities landed were significantly high. The landings at Sakthikulangara consisted of smaller sized seahorses of mean weight 2.92±1.61g, and mean length 80±0.78mm. The catch was dominated by *H. trimaculatus* and also included *H. borboniensis*. The annual seahorse landings at Sakthikulangara/ Neendakara harbour was estimated as 5,61,418 numbers, which worked out to be 1.6 MT. The males were found to be 23.37% more than the females in number. The peak landing was observed during the post monsoon and northeast monsoon with maximum in the month of November (1,69,203) number.

Seahorses were occasionally collected at Vizhinjam, by country crafts and mechanized vessels, which set out for gill netting. The seahorses, which might

Table 2. Annual landing of seahorses by shrimp trawlers of Sakthikulangara / Neendakara Harbour during the year 2001

Boat / Month	Days		I	II	III	IV	V	VI	VII	VIII	IX	X	Mean Male	Mean Female	Total days of fishing	Mean no of boats/ month	Total Males	Total Females	Total number of seahorses caught
January	1	Male	0	0	1	1	0	0	0	0	0	2	0.40		26	1578	10257	8206	18463
		Female	2	0	0	1	0	0	0	0	0	0		0.30					
	2	Male	0	1	0	0	0	0	0	0	0	0	0.10						
		Female	0	1	0	0	0	0	0	0	0	0		0.10					
February	1	Male	0	0	0	0	0	0	0	1	1	0	0.20		25	1633	10206	16330	26536
		Female	0	0	0	0	0	0	0	1	1	2		0.40					
	2	Male	0	0	1	1	0	0	0	0	1	0	0.30						
		Female	1	0	1	0	0	0	0	2	0	0		0.40					
March	1	Male	0	0	0	0	0	0	0	0	0	0	0.00		28	1650	9240	11550	20790
		Female	0	0	0	1	0	0	0	0	0	0		0.10					
	2	Male	1	1	2	0	0	0	0	0	0	0	0.40						
		Female	1	1	0	0	0	2	0	0	0	0		0.40					
April	1	Male	0	0	2	0	0	0	0	0	0	1	0.30		26	1650	8580	12870	21450
		Female	0	0	0	1	1	2	0	0	0	0		0.40					
	2	Male	0	0	0	0	0	1	0	0	0	0	0.10						
		Female	0	0	0	0	1	1	0	0	0	0		0.20					
May	1	Male	0	0	0	0	0	2	0	0	1	0	0.30		27	1750	11813	4725	16538
		Female	0	0	0	0	0	0	0	0	1	0		0.10					
	2	Male	0	0	2	0	0	0	0	0	0	0	0.20						
		Female	0	0	1	0	0	0	0	0	0	0		0.10					
June	1	Male											0.00			0	0	0	0
		Female												0.00					
	2	Male											0.00						
		Female												0.00					

Boat / Month	Days		I	II	III	IV	V	VI	VII	VIII	IX	X	Mean Male	Mean Female	Total days of fishing	Mean no of boats/ month	Total Males	Total Females	Total number of seahorses caught
July	1	Male											0.00		13	1800	10530	10530	21060
		Female												0.00					
	2	Male	0	2	2	0	4	0	1	0	0	0	0.90						
		Female	0	1	4	0	3	0	1	0	0	0		0.90					
August	1	Male	0	2	1	0	1	2	0	2	1	2	1.10		27	1550	37665	33480	71145
		Female	0	1	2	0	1	2	0	1	1	1		0.90					
	2	Male	0	1	1	2	0	0	1	0	1	1	0.70						
		Female	0	1	1	0	0	0	2	1	0	2		0.70					
September	1	Male	1	2	1	2	8	0	2	1	2	0	1.90		24	975	25740	10530	36270
		Female	2	0	0	0	0	0	1	0	0	0		0.30					
	2	Male	1	0	0	0	0	1	1	0	0	0	0.30						
		Female	0	0	2	0	1	1	2	0	0	0		0.60					
October	1	Male	0	0	0	0	0	0	0	1	0	0	0.10		27	915	1235	7412	8647
		Female	0	0	0	0	0	0	2	1	0	0		0.30					
	2	Male	0	0	0	0	0	0	0	0	0	0	0.00						
		Female	0	0	0	0	0	0	0	0	1	2		0.30					
November	1	Male	3	0	1	0	1	3	0	1	0	3	1.20		26	2503	110633	58570	169203
		Female	0	1	2	0	1	2	0	1	0	1		0.80					
	2	Male	2	1	1	2	4	2	4	5	0	1	2.20						
		Female	2	0	1	0	3	0	2	1	0	1		1.00					
December	1	Male	0	2	1	2	8	0	6	3	0	1	2.30		23	2580	74175	77142	151317
		Female	0	1	1	3	6	0	4	2	0	2		1.90					
	2	Male	0	0	0	1	0	0	1	0	0	0	0.20						
		Female	1	2	0	1	0	0	2	0	1	0		0.70					
Total annual landing																	**310074**	**251344**	**561418**

get entangled with the gill net, were collected. There was no organised trade and the dead seahorses were dried and sold. Seahorses were occasionally landed in Beypore and Puthiyappa fishing harbours in Calicut. They were usually found far off shore, and were said to be associated with seaweeds. Seahorses were seen clinging to seaweeds mainly during the two monsoon periods when the sea became rough, and the water was turbid. Ten specimens were collected from a fisherman, which were identified to be *H. trimaculatus* (8 numbers) and *H. borboniensis* (2 numbers). Seahorses were also occasionally landed at Chavakkad and Chettuva harbours, as a by-catch of shrimp trawlers, or beach landing country craft. They were locally called *pattumeen*, which also included pipefishes and other similar species. They were sometimes caught while clinging to gill nets. The country crafts included *vallams* and catamarans. Seahorses were said to be obtained only from the deep sea. Most of the seahorses caught were dried along with Squilla for use as manure. However, fishermen were aware of the medicinal uses of seahorses, and used them for treating asthma. Seahorses were dried, powdered, and mixed with honey as a remedy for asthma. It was also believed by some of the fishermen that seahorses could prevent epilepsy or other disorders, if kept tied to the body. There was no seahorse catch reported from the Dharmadom landing centre near Thalassery.

4.2. Taxonomy

The results of the study of morphometric data indicated the occurrence of 6 species of seahorses along the Indian coast namely *Hippocampus borboniensis* Dumeril 1870 (Plate 1A, Fig 2), *Hippocampus spinosissimus* Weber 1913 (Plate 1B, Fig 3), *Hippocampus kuda* Bleeker 1852 (Plate 2A, Fig 4), *Hippocampus fuscus* Ruppell 1838 (Plate 2B, Fig 5), *Hippocampus trimaculatus* Leach 1814 (Plate 3A, Fig.6) and *Hippocampus guttulatus* Cuvier 1829 (Plate 3B, Fig 7). The salient features of the six confirmed species are provided in page 82, 84, 87, 89, 92 and 94 and the morphometric data compared in Table 3. There were also 4 doubtful morphotypes (Plate 4 & 5) for which a clear-cut identification could not be made, and the meristic data are presented in Table 4. Variation in overall body shape, relative snout length, coronet height, number of trunk and tail rings, and degree of development of body and tail spines were sufficient to separate the

Plate 1

Hippocampus borboniensis

Hippocampus spinosissimus

Fig 2. ***Hippocampus borboniensis***

Adult height	: 12 - 19 cm
Trunk length	: 2.9 - 6 cm
Tail length	: 7 - 9.5 cm
Head length	: 2.2 - 2.8 cm
Snout length	: 1.2 - 1.3 cm

Hippocampus borboniensis Dumeril 1870

Common name	-	Reunion seahorse
Synonyms	-	None
Adult height	-	12-19 cm
Trunk length	-	2.9 - 6 cm
Trunk rings	-	11
Tail length	-	7.0 - 9.5 cm
Tail rings	-	36
Head length	-	2.2 - 2.8 cm
Snout length	-	1.2 - 1.3 cm
Pectoral fin rays	-	16
Dorsal fin rays	-	17
Coronet	-	low with 5 rounded knobs
Spines (general)	-	well-developed rounded knobs
Eye spines	-	prominent rounded
Cheek spines	-	low rounded
No. of specimens examined	-	241
Other features	-	Usually dusty greenish brown with dusty yellow dots, marbled, and broken lines on head, or dark, uniform colour. Fairly thick snout.

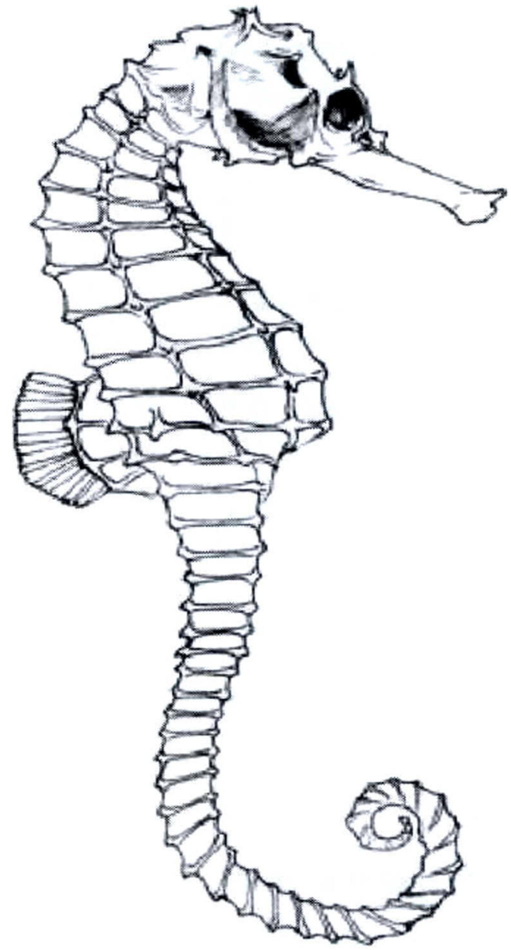


Fig 3. ***Hippocampus spinosissimus***

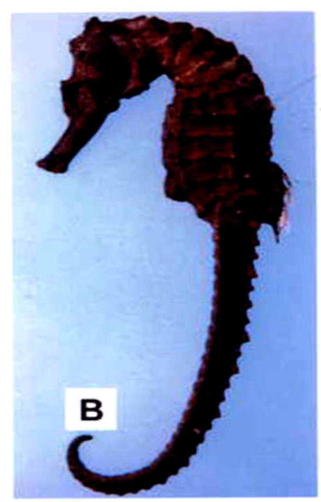
Adult height	: 12 - 19 cm
Trunk length	: 2.8 - 4 cm
Tail length	: 4.5 - 6.5 cm
Head length	: 2 - 3.2 cm
Snout length	: 1.1 - 1.4 cm

Hippocampus spinosissimus Weber 1913

Common name	-	Hedgehog seahorse
Synonyms	-	*H. aimei* (arnei) Route 1916
Adult height	-	12 - 19 cm
Trunk length	-	2.8 - 4.0 cm
Trunk rings	-	11
Tail length	-	4.5 - 6.5 cm
Tail rings	-	36
Head length	-	2.0 - 3.2 cm
Snout length	-	1.1 - 1.4 cm
Pectoral fin rays	-	17
Dorsal fin rays	-	18
Coronet	-	low/medium with 5 sharp spines
Spines (general)	-	well developed, slightly elongated and blunt tipped
Eye spines	-	prominent sharp or rounded
Cheek spines	-	long, prominent, sharp or rounded
No. of specimens examined	-	217
Other features	-	Colour variable; plain or pale with darker 'saddles' across dorso-lateral surface, *and darker cross bands on tail.*

Plate 2

Hippocampus fuscus



Hippocampus kuda

Fig 4. ***Hippocampus kuda***

Adult height	: 5.5 - 16 cm
Trunk length	: 4 - 4.9 cm
Tail length	: 8 - 9.8 cm
Head length	: 2.6 - 3 cm
Snout length	: 0.8 - 1 cm

Hippocampus kuda Bleeker 1852

Common name	-	Yellow seahorse, spotted seahorse
Synonyms	-	*H. moluccensis* Bleeker, 1852b; *H. taeniopterus* Bleeker,1852b; *H. polytaenia* Bleeker,1854b; *H. chinensis* Basilewsky,1855; *H. rhynchomacer* Dumeril,1870; *H. tristis* Castenau,1872; *H. aterrimus* Jordan & Snyder, 1902; *H. hilonis* Jordan & Evermann, 1903; *H. taeniops* Fowler, 1904; *H. horai* Duncker, 1926; *H. kuda multiannularis* Raj, 1941; *H. novaehebudorum* Fowler, 1944.
Adult height	-	5.5 - 16 cm
Trunk length	-	4.0 - 4.9 cm
Trunk rings	-	11
Tail length	-	4.0 - 9.8 cm
Tail rings	-	36
Head length	-	2.6 - 3.0 cm
Snout length	-	0.8 - 1.0 cm
Pectoral fin rays	-	16
Dorsal fin rays	-	17
Coronet	-	low/medium rounded, overhanging at the back, with a cup-like depression in the top; not spiny, sometimes with broad flanges.
Spines (general)	-	body more or less smooth, with low rounded bumps.
Eye spines	-	none or very low
Cheek spines	-	low or prominent, rounded tips.
No. of specimens examined	-	183
Other features	-	Deep head, deep body and thick snout, often totally black colour with a grainy texture, alternatively pale yellow or cream with, fairly large, dark spots (especially females); sometimes sandy coloured, blending in with the surroundings.

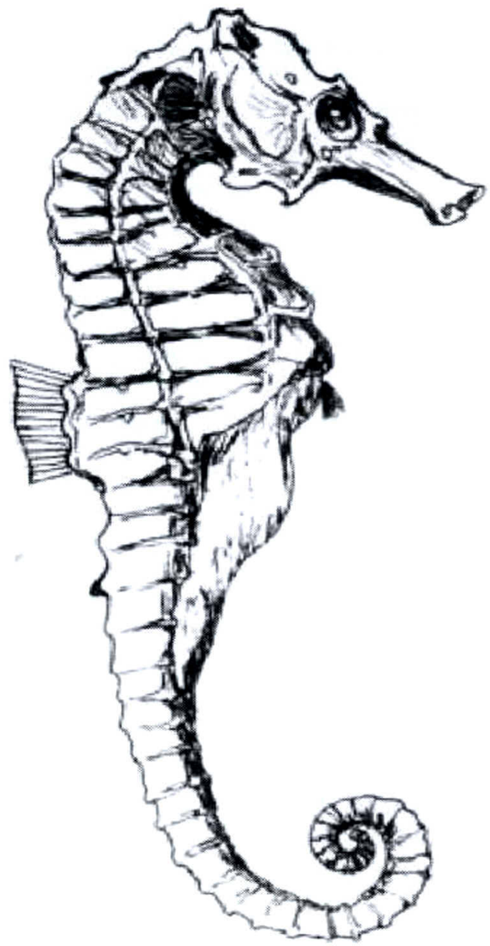


Fig 5. ***Hippocampus fuscus***

Adult height	: 15 - 19.5 cm
Trunk length	: 2.4 - 3.6 cm
Tail length	: 6.3 - 9.8 cm
Head length	: 1.9 - 2.4 cm
Snout length	: 0.7 - 0.9 cm

Hippocampus fuscus Ruppell 1838

Common name	-	Sea pony
Synonyms	-	*H. brachyrhynchus* Duncker 1914 *H. natalensis* von Bonde 1924
Adult height	-	15.0 - 19.5 cm
Trunk length	-	2.4 - 3.6 cm
Trunk rings	-	11
Tail length	-	6.3 - 9.8 cm
Tail rings	-	34
Head length	-	1.9 - 2.4 cm
Snout length	-	0.7 - 0.9 cm
Pectoral fin rays	-	15
Dorsal fin rays	-	16
Coronet	-	low, arch of neck a smooth curve, or slightly raised.
Spines (general)	-	low, smooth to slightly developed.
Eye spines	-	none or very low
Cheek spines	-	none or very low
No. of specimens examined	-	77
Other features	-	large head in proportion to body, usually dark colour, but can be bright yellow.

Plate 3

Hippocampus trimaculatus

Hippocampus guttulatus

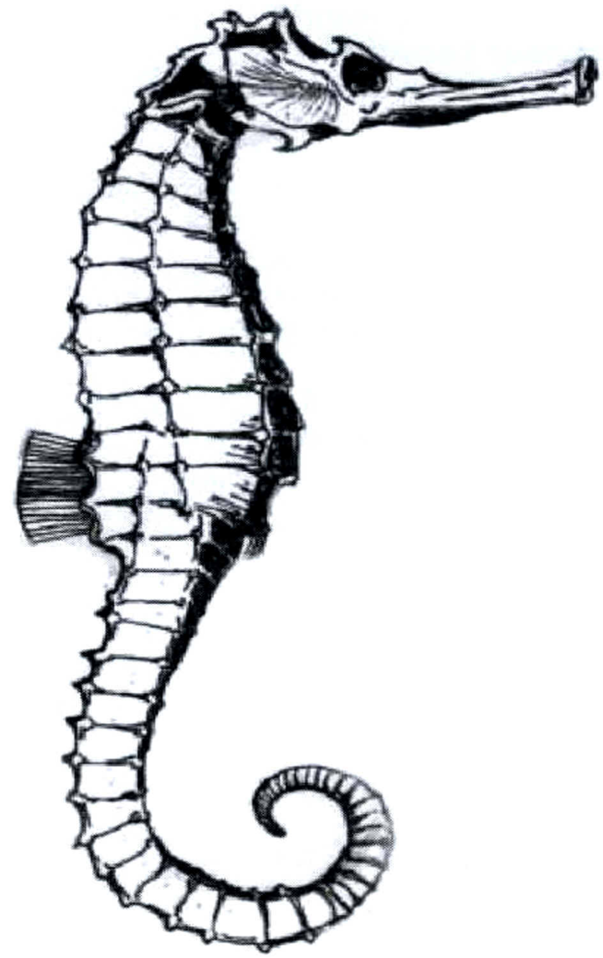


Fig 6. ***Hippocampus trimaculatus***

Adult height	: 8 - 17.8 cm
Trunk length	: 2.6 - 4.3 cm
Tail length	: 5.2 - 7.4 cm
Head length	: 1.5 - 2.3 cm
Snout length	: 0.8 - 1.1 cm

Hippocampus trimaculatus Leach 1814

Common name	-	Three-spot seahorse low-crowned seahorse (Aus) flat-faced seahorse (Aus)
Synonyms	-	*H. mannulus* Cantor 1850; *H. kampylotrachelos* Bleeker, 1854d; *H. manadensis* Bleeker, 1856; *H. planifrons* Peters, 1877; *H. dahli* Ogilby, 1908; *H. takakurae* Tanaka, 1916.
Adult height	-	8.0 - 17.8 cm
Trunk length	-	2.6 - 4.3 cm
Trunk rings	-	11
Tail length	-	5.2 - 7.4 cm
Tail rings	-	40
Head length	-	1.5 - 2.3 cm
Snout length	-	0.8 - 1.1 cm
Pectoral fin rays	-	17
Dorsal fin rays	-	20
Coronet	-	very low, in line with arch of neck, visible as five tiny points.
Spines (general)	-	low and small to slightly raised
Eye spines	-	low, sharp and hook-like
Cheek spines	-	sharp and hook-like
No. of specimens examined	-	120
Other features	-	narrow head, head usually of zebra-striped form. Colour totally black, sandy or golden orange; some specimens 'zebra striped' in brown and white.

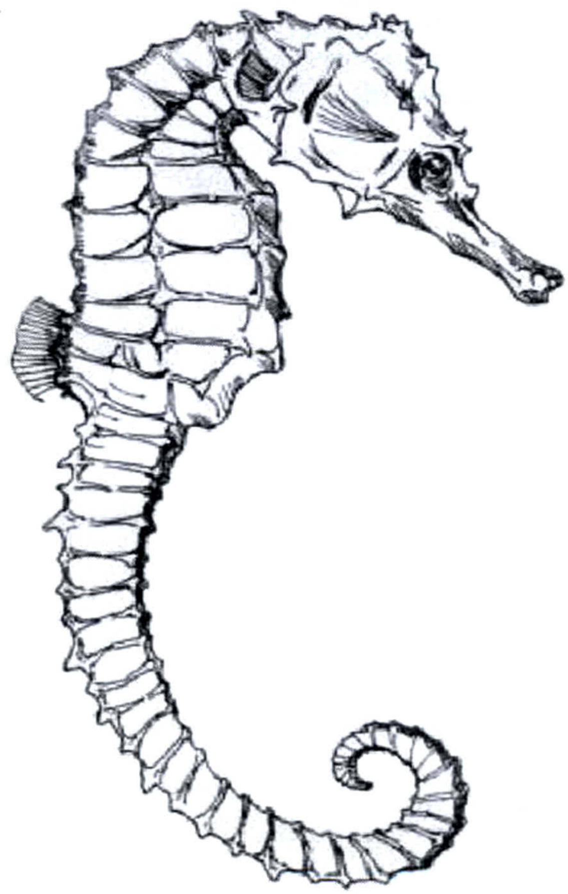


Fig 7. ***Hippocampus guttulatus***

Adult height	: 12 - 20.5 cm
Trunk length	: 3.2 - 6 cm
Tail length	: 5.7 - 10.8 cm
Head length	: 3 - 3.9 cm
Snout length	: 1.1 - 1.2 cm

Hippocampus guttulatus Cuvier 1829

Common name	-	long-snouted seahorse
Synonyms	-	*H. hippocampus microstephanus* Slastenenko 1937, *H. hippocampus microcoronatus* Slastenenko 1938 *H. guttulatus* multiannularis Ginsburg 1937
Adult height	-	12.0 - 20.5 cm
Trunk length	-	3.2 - 6.0 cm
Trunk rings	-	11
Tail length	-	5.7 - 10.8 cm
Tail rings	-	37
Head length	-	3.0 - 3.7 cm
Snout length	-	1.1 - 1.2 cm
Pectoral fin ray	-	18
Dorsal fin rays	-	19
Coronet	-	small but distinct with 5 rounded knobs or blunt points, horizontal plate in front of coronet as high as coronet itself, with a prominent spine at its front edge; coronet not joined smoothly to neck.
Spines (general)	-	medium to well developed with blunt tips.
Eye spines	-	prominent rounded
Cheek spines	-	low or prominent with rounded tips.
No. of specimens examined	-	35
Other features	-	variable brown colour; prominent white spots on the body (often with a dark ring around them) which tend to coalesce into horizontal wavy lines. May be very much mottled or with pale 'saddles' across dorso-lateral surface.

Table 3. Morphometric and meristic data of seahorse species identified from Indian coast

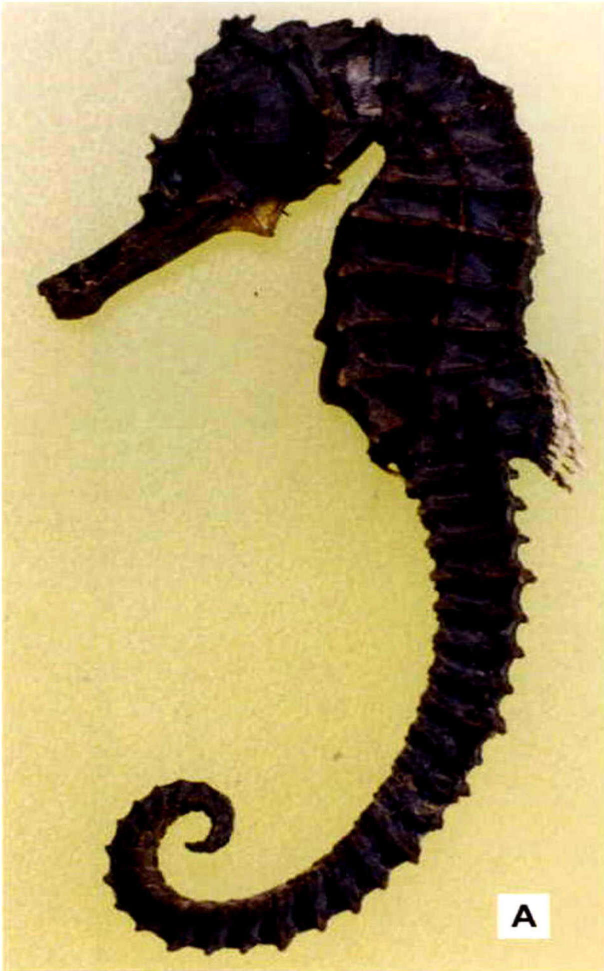
	H.borboniensis	*H. spinosissimus*	*H. kuda*	*H. fuscus*	*H. trimaculatus*	*H. guttulatus*
MORPHOMETRICS	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
Standard length	12-16	7.5-12	13-16	9-14	8-11.8	9-17
Trunk length	2.9-6	2.8-4	4-4.9	2.4-3.6	2.6-4.3	3.2-6
Tail length	7-9.5	4.5-6.5	8-9.8	6.3-9.8	5.2-7.4	5.7-10.8
Head length	2.2-2.8	2-3.2	2.6-3	1.9-2.4	1.5-2.3	3-3.9
Snout length	1.2-1.3	1.1-1.4	0.8-1	0.7-0.9	0.8-1.1	1.1-1.2
MERISTICS	(number)	(number)	(number)	(number)	(number)	(number)
No of trunk rings	11	11	11	11	11	11
No of Tail rings	36	36	36	34	40	37
Pectoral fin rays	16	17	16	15	17	18
Dorsal fin rays	17	18	17	16	20	19
Coronet	low with 5 rounded knobs	medium with 5 sharp spines	low-medium rounded, over-hanging at the back, with a cup-like depression in the top	very low, arch of neck a smooth curve	very low, in line with arch of the neck, visible as 5 tiny points	small, but distinct with 5 round knobs, horizontal plates in front of the coronet. Coronet not joined smooth to the neck.

Plate 4

Morphotype I

Morphotype II

Plate 5



Morphotype III

Morphotype IV

Table 4. Morphometric and meristic data of doubtful seahorse morphotypes identified from Indian coast

	Morphotype I	*Morphotype II*	*Morphotype III*	*Morphotype IV*
MORPHOMETRICS	(cm)	(cm)	(cm)	(cm)
Height	11.40-14.80	12.20-15.60	14.60-17.30	11.80-15.20
Trunk length	2.96-3.84	4.51-5.77	4.06-4.81	2.78-3.58
Tail length	6.88-8.93	7.16-9.16	9.19-10.88	7.03-9.05
Head length	1.83-2.37	2.56-3.29	2.47-2.92	2.00-2.57
Snout length	0.91-1.19	1.06-1.36	1.11-1.32	0.87-1.12
MERISTICS	(number)	(number)	(number)	(number)
No of trunk rings	11	11	11	11
No of Tail rings	36	35	36	34
Pectoral fin rays	17	16	14	18
Dorsal fin rays	17	17	13	18
Eye spines	double	very low	double unequal	prominent rounded
Cheek spines	double on the left side and single spine on the right side	prominent	prominent rounded tips	prominent
Coronet	high coronet with five distinct knobs	very high with five distinct spines	medium height with five knobs	low with five short spines

specimens by eye into different morphotypes which were identified as distinct species. The variation in body colour was not a distinguishing character to outline the species, since body colours like black, white, yellow and red were found for the same species (Plate 6 & 7). This might be the manifestation in response to the environment they live in the sea.

Species composition was found to vary with location (Table 5 and Fig 8). In the Thondi area, *H. borboniensis* dominated the catch with a share of 27.96%, followed by *H. spinosissimus* (22.14%). *H. kuda* represented 20.90%, *H. trimaculatus 14%, and H. fuscus* 9%. *H. guttulatus* was represented by only 4% and the doubtful morphotypes 2%. In Kerala only two species were found. The seahorse fishery of Chavakad was entirely of *H. trimaculatus* whereas in Sakthikulangara, Kochi, and Calicut, *H. trimaculatus* and *H. borboniensis* were present at ratios of 2.75:1, 4:1 and 4:1 respectively.

4.3. Sex ratio

Sex ratio of the annual landing of seahorses at Thondi (Table 6) showed that the male and female ratio was almost the same with mean marginal increase of 0.814 for the females in the catches. The monthwise analysis of sex ratio showed that males were more during the period from May to October reaching as high as 60.99% of the total catch in August. During the period from November to April, females dominated the pooled data of seahorse landing in Thondi reaching maximum value of 63.94% in February. Males with carrying brood pouch seen throughout the year suggested that seahorses in general or at least a few species of seahorses seen in Palk Bay were year round breeders. The very high numbers of carrying males (i.e. 90.85% or 3743 numbers in July; 81.19% or 4239 numbers in August and 73.24% or 457 numbers in September) in the total population of males suggested that the breeding season of seahorses of Thondi could be June to September with peaks in July and August. It was also seen from the data that males were caught more during the breeding season when they were carrying (May to October). In other periods of the year when breeding was very less, females constituted the major fishery.

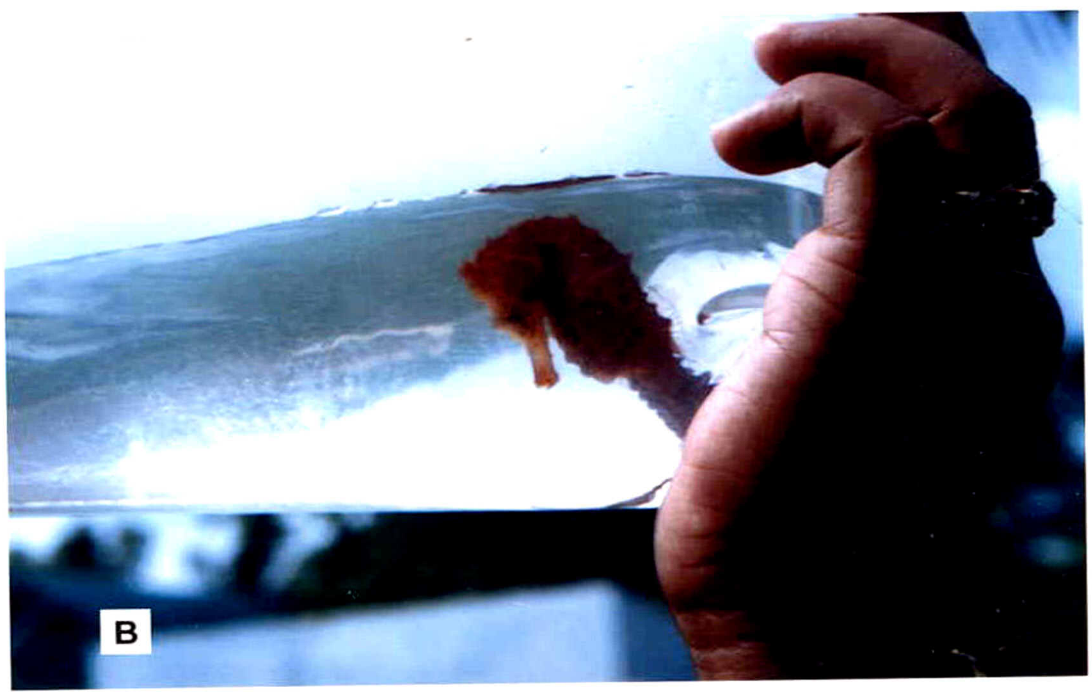
Plate 6

Black Seahorse

White Seahorse

Plate 7

Yellow Seahorse



Red seahorse

Table 5. Mean percentage composition of each species of seahorses from different landing centres in India

Landing centre / species	Thondi	Sakthikulangara Neendakara /	Chavakad	Kochi	Calicut
H. borboniensis	27.96%	26.67%		20%	20%
H. spinosissimus	22.14%				
H. kuda	20.90%				
H. trimaculatus	14.00%	73.33%	100%	80%	80%
H. fuscus	9.00%				
H. guttulatus	4.00%				
Doubtful morphotypes	2.00%				

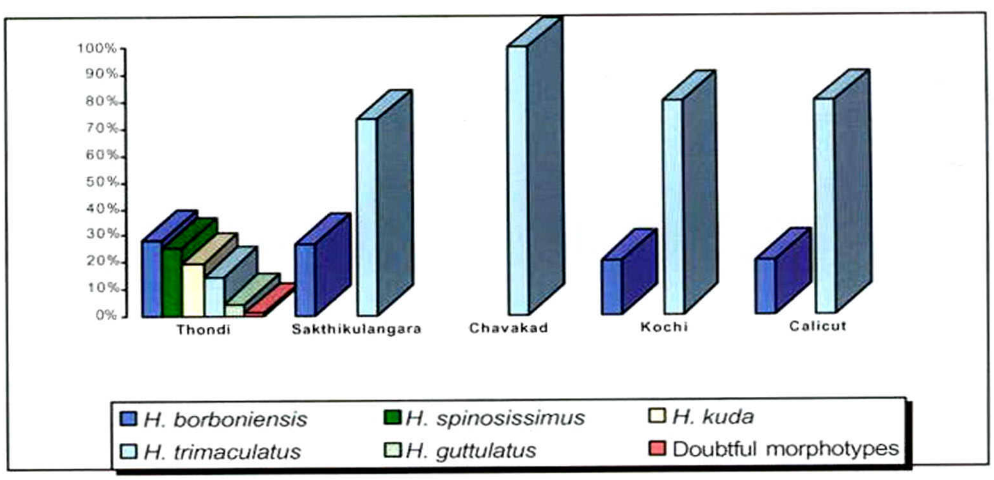


Fig 8. Mean percentage composition of each species of seahorses from different landing centres in India

Table 6. Sex ratio and the occurrence of mature males of *Hippocampus kuda* at Thondi in 2001

Month	Total No obtained	Percentage		Male-female ratio	Chi-square value	Probability	Total males with carrying brood pouch	Percentage carrying brood pouch in male population
		Male	Female					
January	362	40.88	59.12	1:1.446	3.32	0.05<P<0.1	12	8.1
February	721	36.06	63.94	1:1.773	7.77	0.05>P>0.1	18	6.92
March	329	44.68	55.32	1:1.238	1.13	0.05<P<0.1	14	9.52
April	430	47.21	52.79	1:1.118	0.35	0.05<P<0.1	17	11.56
May	1079	50.97	49.03	1:0.962	0.038	0.05<P<0.1	92	16.73
June	1382	53.98	46.02	1:0.853	0.63	0.05<P<0.1	216	28.95
July	7104	58	42	1:0.724	2.56	0.05<P<0.1	3743	90.85
August	8560	60.99	39.01	1:0.64	4.83	0.05>P>0.1	4239	81.19
September	1201	51.96	48.04	1:0.925	0.15	0.05<P<0.1	457	73.24
October	1323	52.99	47.01	1:0.887	0.36	0.05<P<0.1	315	44.94
November	544	47.98	52.02	1:1.084	0.082	0.05<P<0.1	73	27.97
December	525	44	56	1:1.273	0.021	0.05<P<0.1	79	34.2

At Neendakara/Sakthikulangara area the males and females obtained throughout the 12-month period of study remained more or less the same, with slight domination of males by 23.37% (Table 2). Males with inflated brood pouch were observed during October to November months from this region suggesting those months to be the breeding season. This also coincided with the peak landings of seahorses.

4.4. Length-weight relationship

The results on the analysis of length-weight relationship of the males and females of *H. kuda* are depicted in Fig 9 and Fig 10 and the data presented in Table 7. The results revealed that the growth pattern could not be considered to follow the standard cubic form. The b value was found to be significantly different from 3 for both males (1.103592) and females (1.231822). The relationship was obtained as $\log W = -0.35792 + 1.103592 \log L$ or $W = 0.438615 (L^{1.103592})$ for males, and $\log W = -0.43118 + 1.231822 \log L$ or $W = 0.370531 (L^{1.231822})$ for females of *H. kuda* collected from Thondi during 2001.

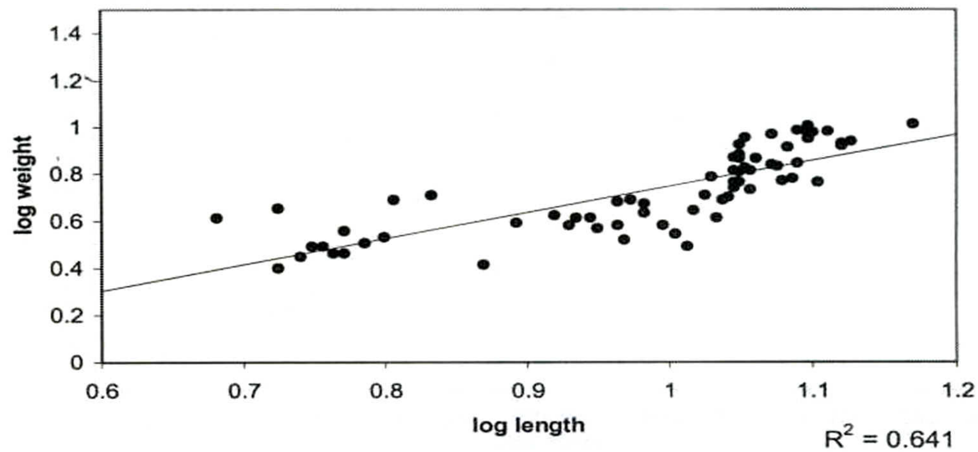
4.5. Length frequency analysis

The length frequency distribution of different species of seahorses at Thondi are provided in Fig 11 to Fig 16. The annual length frequency distribution of the *H. borboniensis* (Fig 11) showed that the fishery was contributed by size range of 120-190mm with the dominant size group being 145-175mm. The landings of *H. spinosissimus* (Fig 12) had also shown a similar size distribution ranging from 120-180mm with the majority being a size class of 145-165mm. Similarly for *H. kuda* (Fig 13) the catch was contributed by seahorses of 45 to 165 mm size. The dominant size class of individuals in the catch ranged from 105 to 145 mm. Seahorses of length 80-170mm contributed to the *H. trimaculatus* (Fig 14) fishery with the majority being of the size 110-165mm. The *H. guttulatus* (Fig 15) fishery consisted of a bigger size class of 120-200mm with a major group of 150-190mm. *H. fuscus* (Fig 16) consisted of a size class of 140-190mm.

The growth and catch curves derived from the analysis of length frequency data by FiSAT II programme are given in Fig 17, Fig 18 and Fig 19.

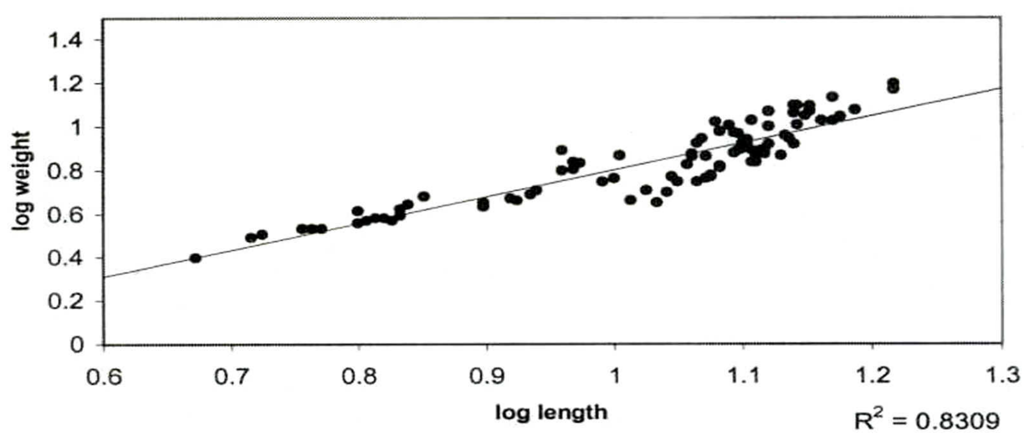
Table 7. Length and weight measurements of *Hippocampus kuda* from Thondi

sl. no.	Male		Female	
	Length (cm)	Weight (g)	Length (cm)	Weight (g)
1	12.3	7.0	13.7	8.8
2	11.4	5.4	11.5	7.5
3	12.7	5.8	10.6	5.1
4	10.9	4.9	13.2	8.3
5	13.4	8.7	14.2	11.8
6	11.1	5.8	12.3	10.1
7	12.3	9.7	10.1	7.4
8	12.5	9.3	10.0	5.8
9	11.4	6.5	11.6	8.4
10	11.0	5.0	13.9	12.5
11	11.2	8.4	11.5	7.3
12	12.5	10.1	12.8	7.8
13	12.6	9.5	12.1	6.6
14	11.8	9.3	15.0	11.1
15	12.0	5.9	12.1	9.5
16	11.1	6.5	11.0	5.0
17	11.5	7.3	13.1	7.8
18	9.9	3.8	15.4	11.9
19	8.9	3.7	11.8	7.3
20	11.2	5.8	16.5	14.7
21	9.2	3.8	11.1	5.9
22	11.3	9.0	13.8	8.3
23	11.2	7.6	11.9	6.0
24	13.4	8.7	12.8	6.9
25	10.8	4.1	14.2	11.7
26	9.3	3.3	12.6	8.4
27	10.1	3.5	12.7	8.3
28	12.5	8.9	14.2	12.4
29	11.3	6.7	12.9	6.9
30	14.8	10.3	13.5	7.4
31	11.1	5.5	11.8	5.8
32	12.2	6.0	13.6	9.1
33	11.9	6.8	12.9	7.4
34	11.8	6.9	11.6	5.6
35	10.3	3.1	11.2	5.6
36	10.7	6.1	12.6	8.4
37	11.2	6.4	14.1	11.2
38	12.9	9.6	9.8	5.6
39	9.6	4.7	13.2	10.0
40	10.4	4.4	13.1	7.9
41	11.1	7.4	12.5	7.8
42	9.2	4.8	14.5	10.7
43	13.2	8.5	12.4	9.4
44	8.3	4.2	10.8	4.5
45	11.2	7.3	12.4	7.6
46	8.5	3.8	11.9	5.9
47	11.2	7.5	16.5	15.7
48	8.6	4.1	11.4	6.7
49	7.8	3.9	13.8	11.5
50	11.5	7.3	10.3	4.6
51	10.6	5.1	12.7	8.7
52	13.2	8.3	13.0	7.8
53	12.1	8.2	9.1	7.8
54	9.4	4.9	11.2	5.6
55	9.6	4.3	12.8	10.7
56	8.8	4.1	13.8	12.5
57	7.4	2.6	12.0	10.5
58	5.6	3.1	12.6	7.9
59	4.8	4.1	11.7	8.8
60	5.3	4.5	12.1	6.5
61	6.8	5.1	14.8	13.6
62	5.9	3.6	13.9	10.2
63	6.4	4.9	14.8	10.6
64	6.1	3.2	13.1	7.5
65	5.3	2.5	13.2	11.7
66	5.5	2.8	12.5	9.3
67	5.7	3.1	5.2	3.1
68	5.8	2.9	6.3	4.1
69	5.9	2.9	5.8	3.4
70	6.3	3.4	6.8	4.2
71			5.9	3.4
72			6.7	3.7
73			6.5	3.8
74			5.7	3.4
75			6.3	3.6
76			4.7	2.5
77			5.3	3.2
78			5.3	3.2
79			6.6	3.8
80			6.9	4.4
81			7.1	4.8
82			6.4	3.7
83			6.8	3.9
84			7.9	4.5
85			7.9	4.3
86			8.3	4.7
87			8.4	4.6
88			8.6	4.9
89			8.7	5.1
90			9.1	6.3
91			9.3	6.4
92			9.4	6.8
93			9.3	6.9
Mean	5.4914	3.1828	6.1140	4.0161



log W = 0.438615 + 1.103592 log L

Fig 9. Length - weight relationship of *Hippocampus kuda* males at Thondi



log W = 0.370531 + 1.231822 log L

Fig 10. Length - weight relationship of *Hippocampus kuda* females at Thondi

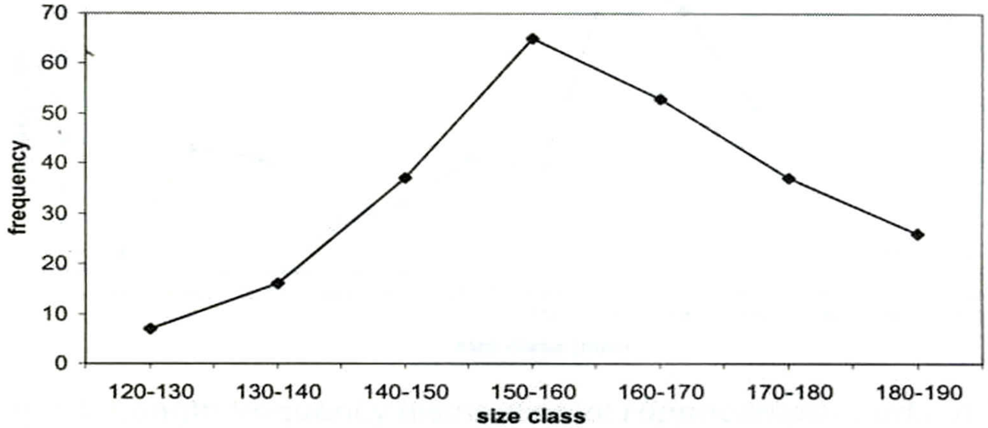


Fig 11. Length frequency distribution of *Hippocampus borboniensis* at Thondi in 2001

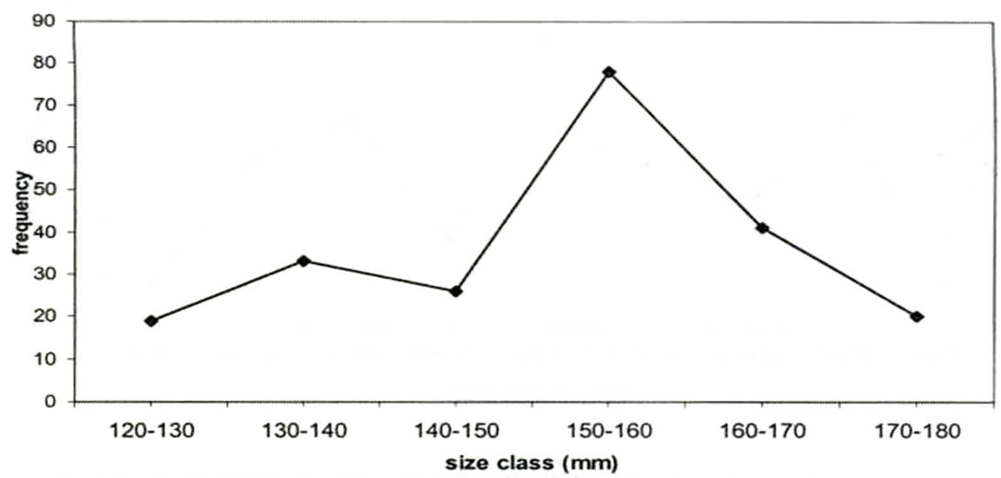


Fig 12. Length frequency distribution of *Hippocampus spinosissimus* at Thondi in 2001

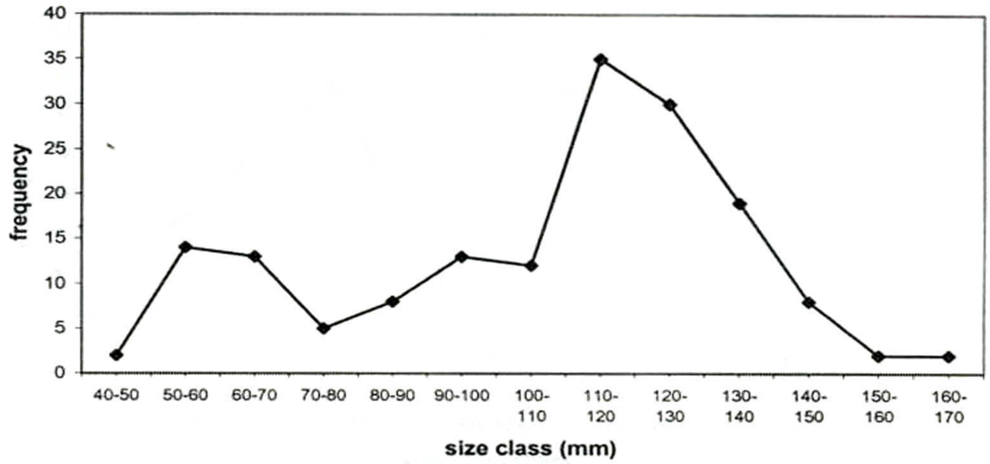


Fig 13. Length frequency distribution of *Hippocampus kuda* at Thondi in 2001

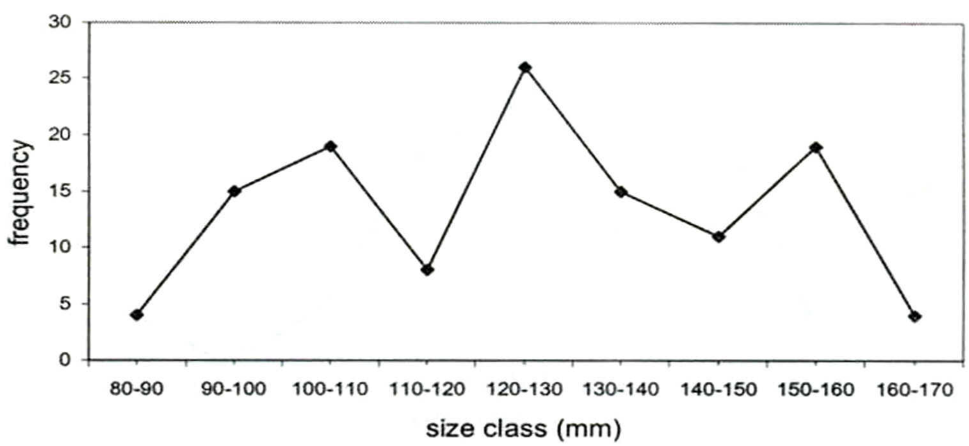


Fig 14. Length frequency distribution of *Hippocampus trimaculatus* at Thondi in 2001

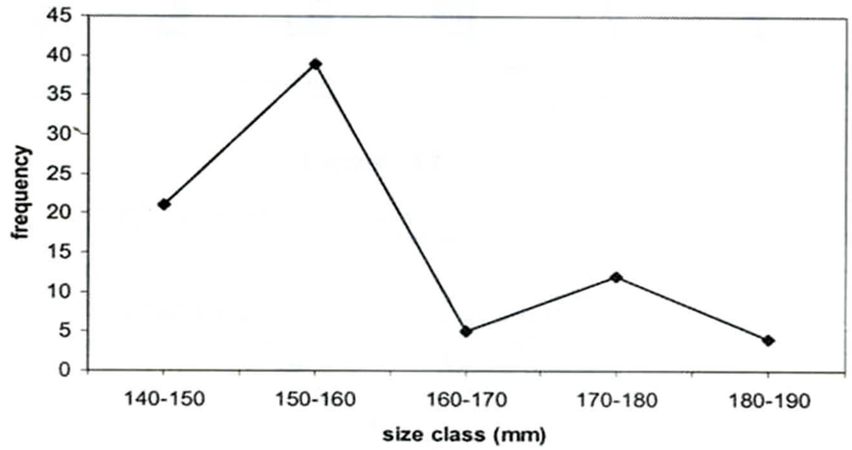


Fig 15. Length frequency distribution of *Hippocampus fuscus* at Thondi in 2001

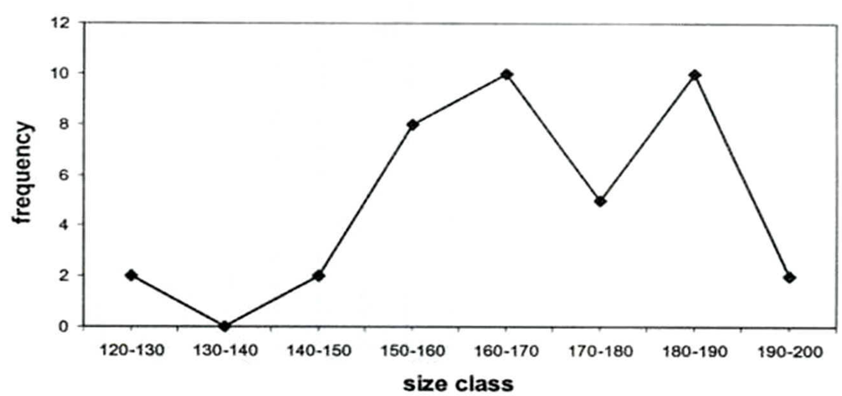


Fig 16. Length frequency distribution of *Hippocampus guttulatus* at Thondi in 2001

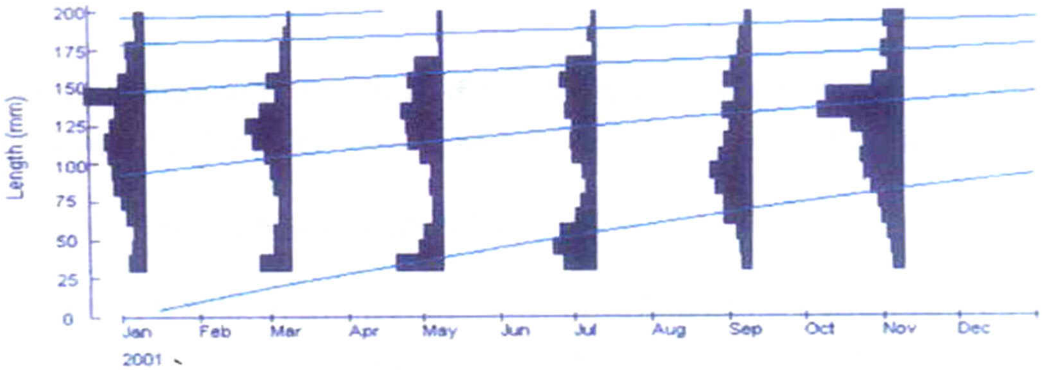


Figure. 17

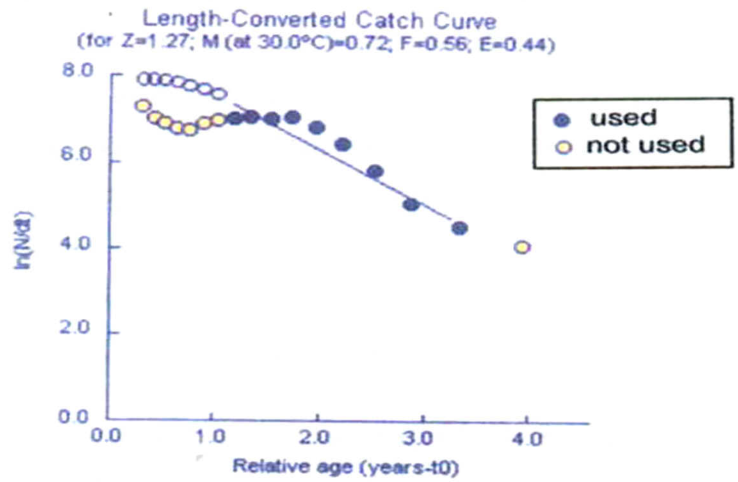


Figure. 18

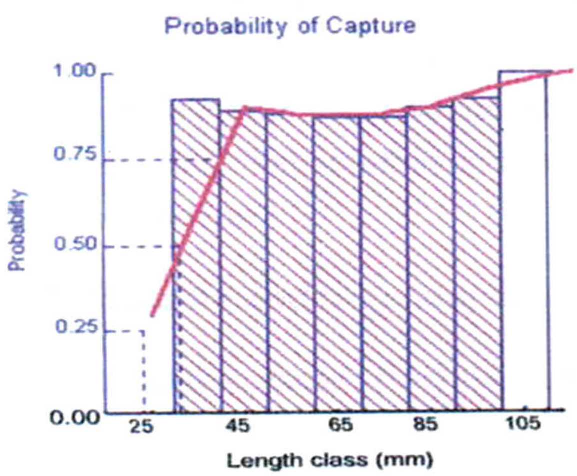


Figure. 19

Figure 17. Length frequency data of *Hippocampus kuda* from Thondi with superimposed growth curve, as estimated using FiSAT II Package for analysis by Bhattacharya method and a Gulland and Holt Plot for estimation of L∝= 220.52 mm, K = 0.55 /year & Z = 1.27 /year

Figure 18. Catch curve for *Hippocampus kuda* based on length frequency data from Thondi in 2001

Figure 19. Probability of capture

These led to the following growth and mortality parameter estimates as Lα = 220.52 mm, K = 0.55 $year^{-1}$, Z = 1.27 $year^{-1}$, M = 0.72 $year^{-1}$, F=0.56 $year^{-1}$ and E=0.44.

4.6. Gut content analysis

The results of the gut content analysis of *H. kuda* are depicted in Table 8 and Fig 20. The gut of *H. kuda* contained mostly crustaceans, dominated by copepods (calanoids, cyclopoids and harpacticoids) forming 22.84% followed by peracarids (mysids and cumaceans), which formed 22.12%. Amphipods (gammarids and amphithoids) and isopods also formed a major share (20.86%). The Decapod larvae and small adult caridean shrimps had a share of 20.67%, apart from a few euphausids (2.36%). Thus crustaceans dominated 88.85% of the gut contents of *H. kuda*. Among the rest, 8.56% comprised of unidentifiable semi-digested matter, and 2.59% sand or other inorganic materials. In many specimens, the mysids and other crustaceans had their original shape retained inside the gut.

Observation of feeding of *H. kuda* in captivity has shown that while feeding *H. kuda* brought its snout within 1cm of the prey. The mouth then protruded forward in a swift inhalant current, sucking the prey into the mouth. The adult seahorses were observed to feed quickly on cultured *Artemia* adults and small freshwater prawns in this manner. The hatchlings were also seen to have the same feeding habit wherein they first scrutinised the prey such as copepods before sucking in by a swift inhalant motion.

4.7. Maturity and breeding season

The condition factor (Kn) plotted against log length showed that the males (Fig 21) attained first sexual maturity at 6.607 cm and females (Fig 22) at 7.799cm of length. *H. kuda* hatchlings grown in aquarium tanks in the present study, reared up to 8 months on a diet of copepods, enriched brine shrimp nauplii and adult brine shrimp, and small pelaemonid prawns attained maturity at 6 months of age, which was visible by the development of brood pouch in the males (at a length of 7.3cm) The average Kn plotted against months for one year in 2001 showed that the peak breeding season at Thondi extended from June to August with the males attaining matured condition in June (Fig 23) and the females in August (Fig 24). The presence of males with carrying brood pouch (Table 6) throughout

Table 8. Gut contents of *Hippocampus kuda* collected from Thondi

Gut contents	Frequency of occurrence (%)	Percentage volume Mean±S.D
CRUSTACEA	100	88.85± 4.19
Copepoda	19.2	22.84 ± 4.83
Calanoida	9.8	8.85 ± 2.74
Cyclopoida	2.1	11.18 ± 4.09
Harpacticoida	7.3	2.82 ± 1.67
Amphipoda	37.8	15.07 ± 4.92
Gammaridae	19.6	4.83 ± 2.12
Ampithoidea	18.2	10.34 ± 5.6
Isopoda	6.3	5.79 ± 2.32
Decapoda	68.9	20.67 ± 4.22
Caridea	67.2	20.55 ± 5.83
Brachyura	1.7	0.12 ± 0.1
Peracaridae	26.4	22.12 ± 1.8
Mysidacea	22.5	19.86 ± 2.6
Cumacea	3.9	2.26 ± 1.17
Eucarida	1.8	2.36 ± 0.13
Euphausiacea	1.8	2.36 ± 0.13
INORGANIC (Sand)	4.1	2.59 ± 1.8
UNIDENTIFIABLE SEMIDIGESTED MATTER	100	8.56 ± 2.84

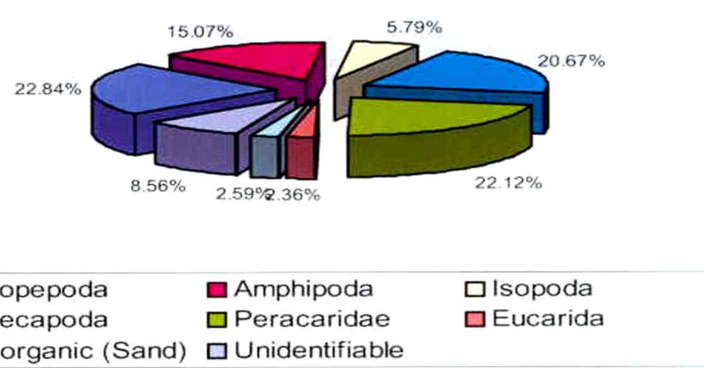


Fig 20. Gut contents of *Hippocampus kuda* collected from Thondi

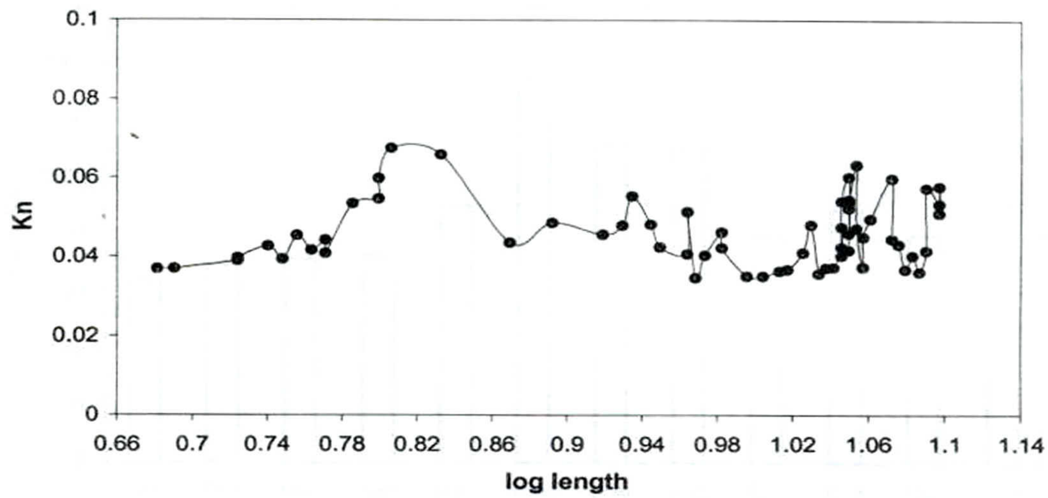


Fig 21. Kn against length for males of *Hippocampus kuda* (size at first maturity – 6.607 cm)

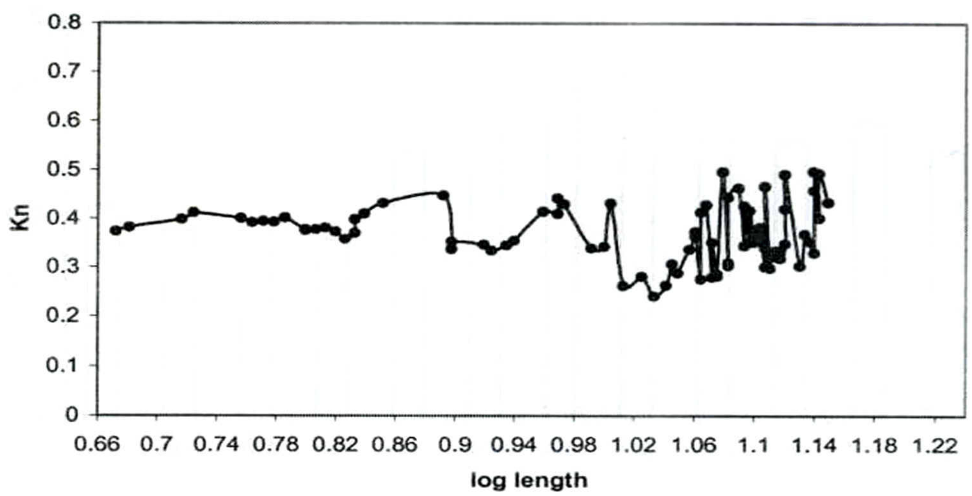


Fig 22. Kn against length for females of *Hippocampus kuda* (size at first maturity – 7.799 cm)

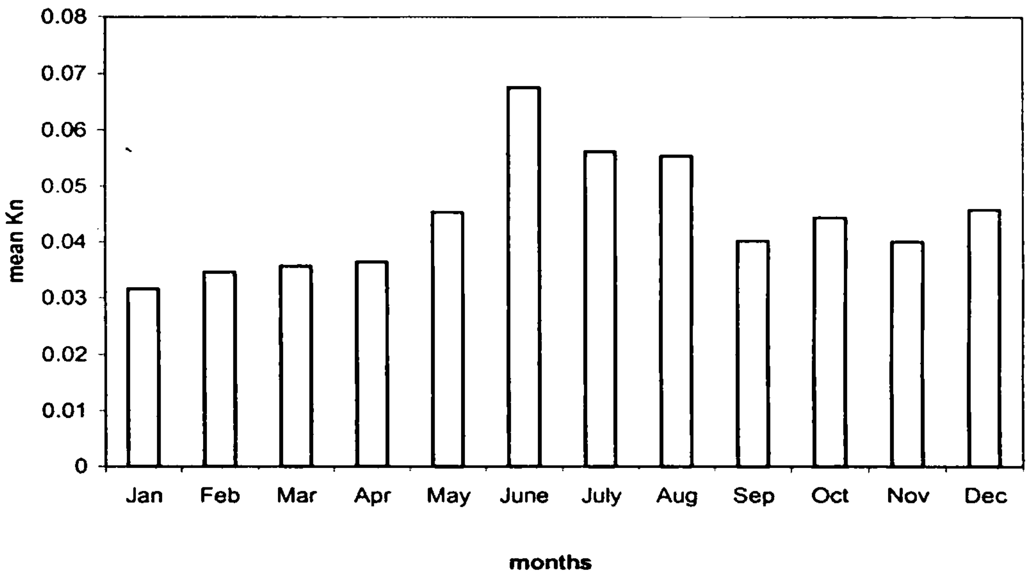


Fig 23. Kn against months for males of *Hippocampus kuda* at Thondi in 2001

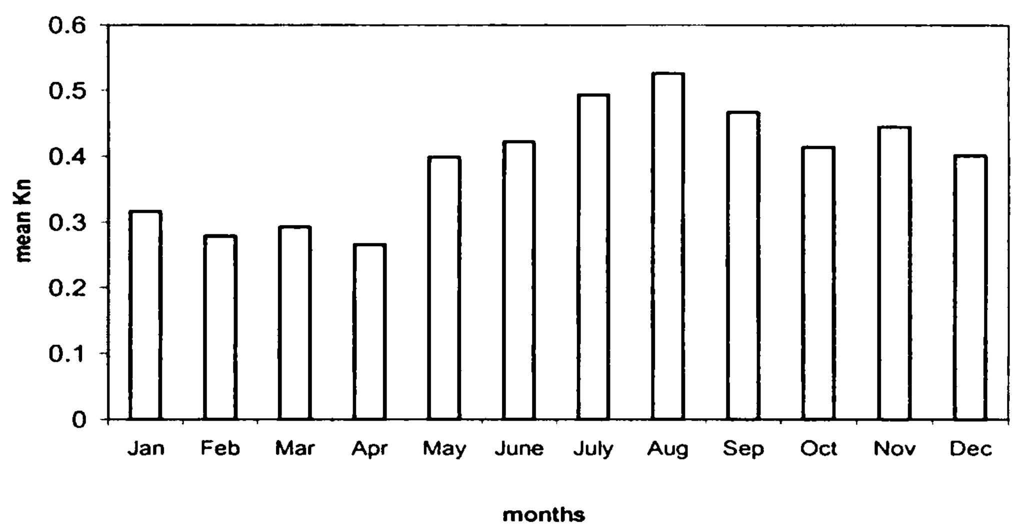


Fig 24. Kn against months for females of *Hippocampus kuda* at Thondi in 2001

the year suggested that the seahorses are year round breeders. The very high percentage of carrying males in the months of June, July and August showed that the peak breeding season is from July to August, with the maximum in August.

4.8. Fecundity and ova diameter

The ova of *H. kuda* are large, and pear shaped, and reddish in colour, adhering to one another. Fecundity ranged from 658 to 823 ova per each adult female seahorse. The ova diameter varied from 0.5 to 0.8 mm (Fig 25). The fecundity obtained was 56.8 g^{-1} body weight of the female. However, when the hatch fecundity of male was determined, the hatchlings (Table 9) ranged from 328 to 495. The mean hatch fecundity was obtained as 37.08 g^{-1} body weight of male.

4.9. Courtship and breeding

Seahorses undergo courtship and breeding under captive conditions without any inducement. The seahorse *H. kuda* displayed distinct patterns of courtship and mating behaviour when observed in glass tanks, during the study. The initial courtship behaviour was observed on every day morning soon after day light. The fish that remained immobile during most of the night came together to take positions side-by-side, engaging in courtship rituals. There were distinct phases in courtship behaviour of seahorses that could be observed in a glass tank.

4.9.1. Brightening

The males underwent rapid change in body colouration from normal body colour (varying from black to white) to lighter body colour in most of the body excluding portions of the head and the dorsal midline that remained dark. During courtship interactions, a male and a female came together and both fish exhibited brightened colouration (Plate 8 A). They exhibited a characteristic posture consisting of an erect body with head inclined downward (Plate 8 B).

4.9.2. Quivering

Courtship in this phase was characterized by repeated occurrences of reciprocal quivering, in which one fish quivered and the other responded by quivering within eight seconds. Both the fish were positioned with their bodies

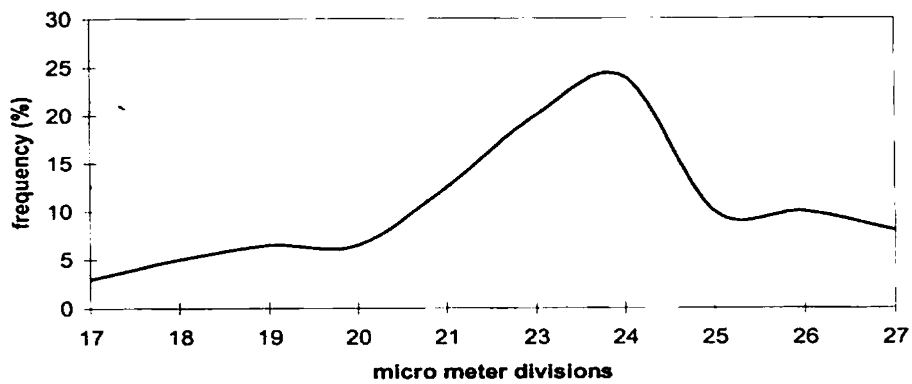


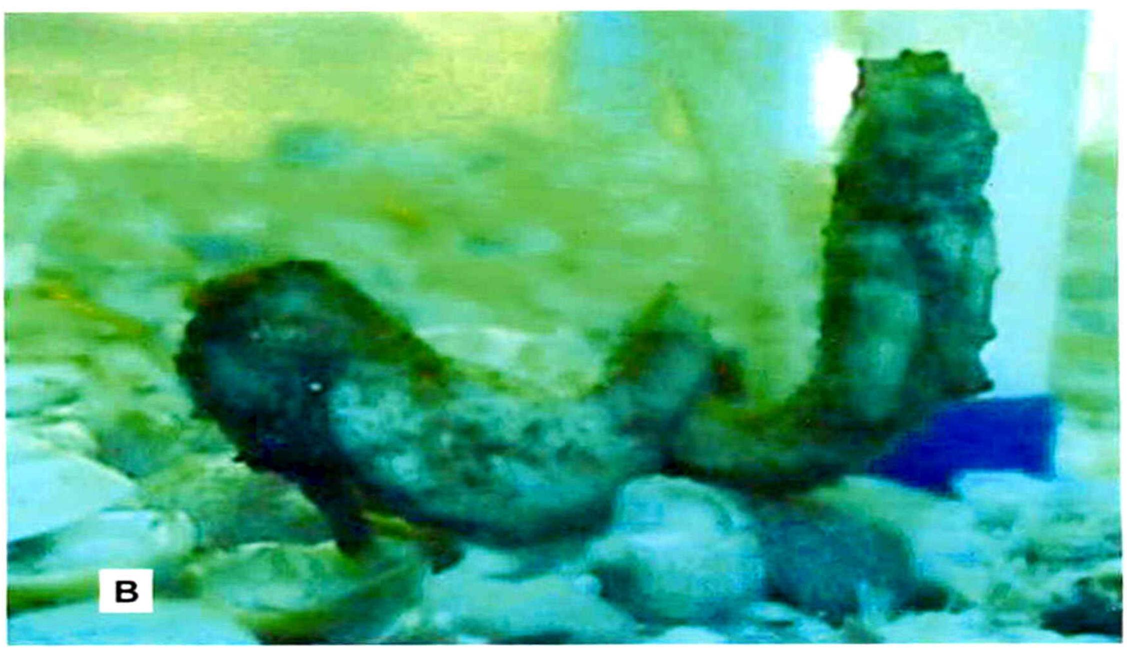
Fig 25. Frequency distribution of ova diameter of *Hippocampus kuda*

Table 9. Hatch fecundity of the males of *Hippocampus kuda* studied in the aquarium

Sl no.	Size of pregnant male length (mm)	weight (g)	No. of hatchlings	Hatch fecundity (no. /g)
1	109	7.85	334	42.55
2	103	6.62	225	33.99
3	112	7.56	351	46.43
4	98	6.61	268	40.54
5	109	8.98	283	31.51
6	113	8.62	275	31.9
7	91	5.51	180	32.67
Mean hatch fecundity				37.08

Plate 8

Brightening



Quivering

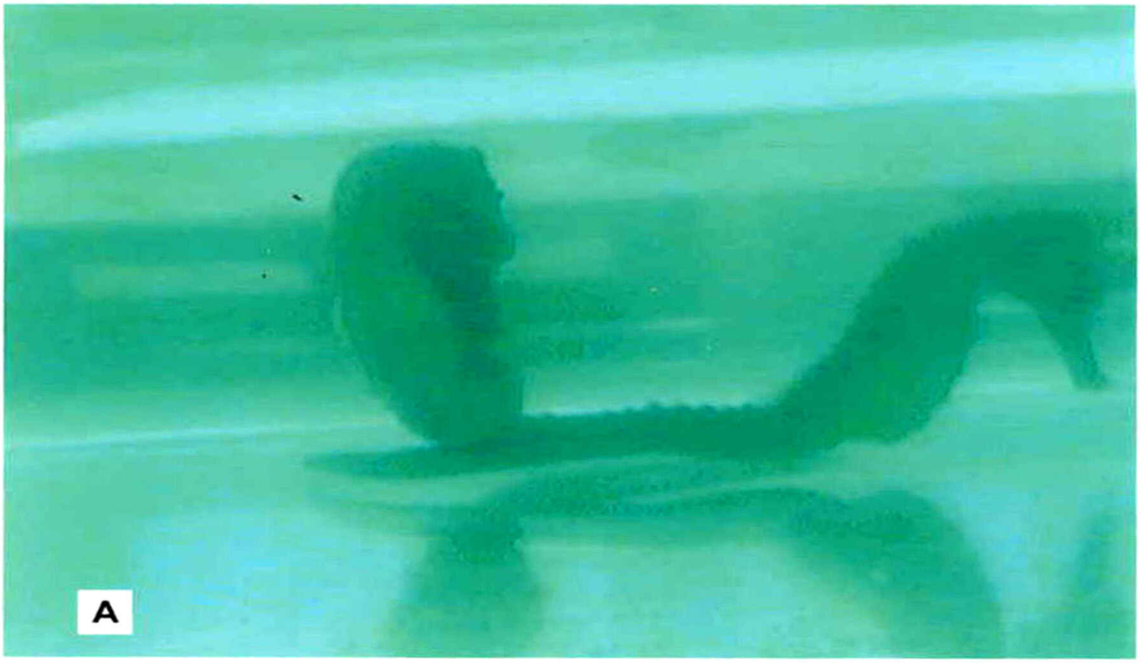
angled outward slightly from the point of attachment on the holdfast, which they shared (Plate 8 B). This was observed even when they were sitting on the bottom of the tank when there was no holdfast nearby. As the male quivered, he rotated his body toward the female, whose initial response was to rotate away from the male (Plate 9 A), before responding by quivering. When the female did not respond, the male was then found to approach other females in the tank for response (Plate 9 B). However, it returned to the same female and resumed the courtship behaviour since there was no other female brightened and ready for courtship.

The male and female came together got entwined with their tails, and the female also became brightened. They then displayed reciprocal quivering, which was terminated when the female moved away. This was repeated about 24 times during the first bout of courtship. This lasted about 13 minutes. Courtship occurred in the morning for two days preceding the day of copulation. Courtship duration was longer on the first day, than on the second day when it lasted only 9 minutes. Mating occurred on the third day, when the pair displayed diverse courtship postures that culminated in mating.

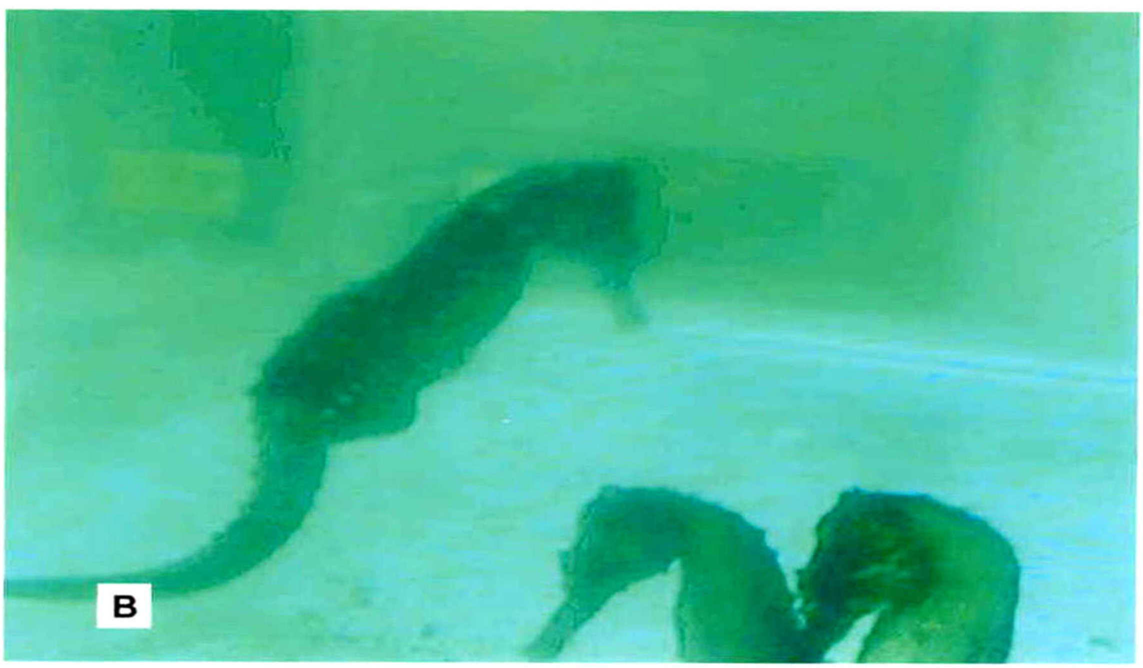
4.9.3. Pointing

On the day of copulation there were distinct phases of courtship behaviour, prior to the event of mating. The males continued to approach females, more often than did females, and males brightened before females did. However, in contrast to the previous courtship interactions, females rather than males almost always displayed the first courtship behaviour in this phase. This was characterized by the females exhibiting the pointing posture (Plate 10 A). In pointing the female raised her head upward toward the water surface to form an oblique angle with body axis and then lowers it again to a horizontal position. As a female pointed, she leaned her body toward the male, who simultaneously leaned away. Males generally responded to female pointing by leaning back toward the female and quivering. Females leaned away as the male quivered, but in contrast to reciprocal quivering, females maintained their position on the common holdfast. Pumping behaviour was displayed by males in all seahorse pairs following the first courtship bout in this stage.

Plate 9

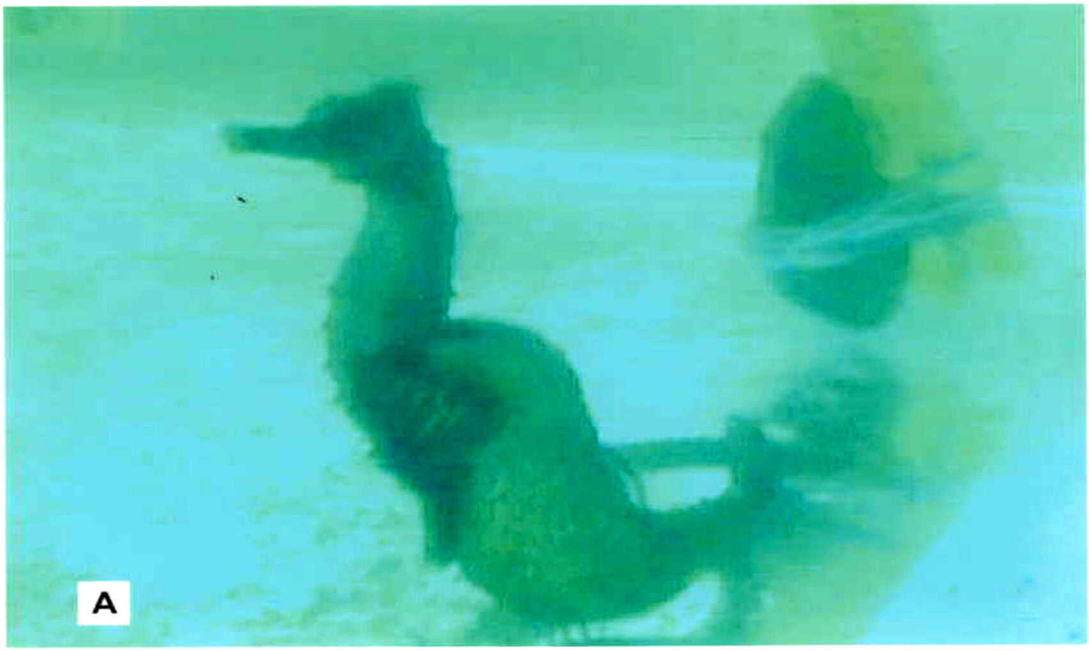


Female response to quivering

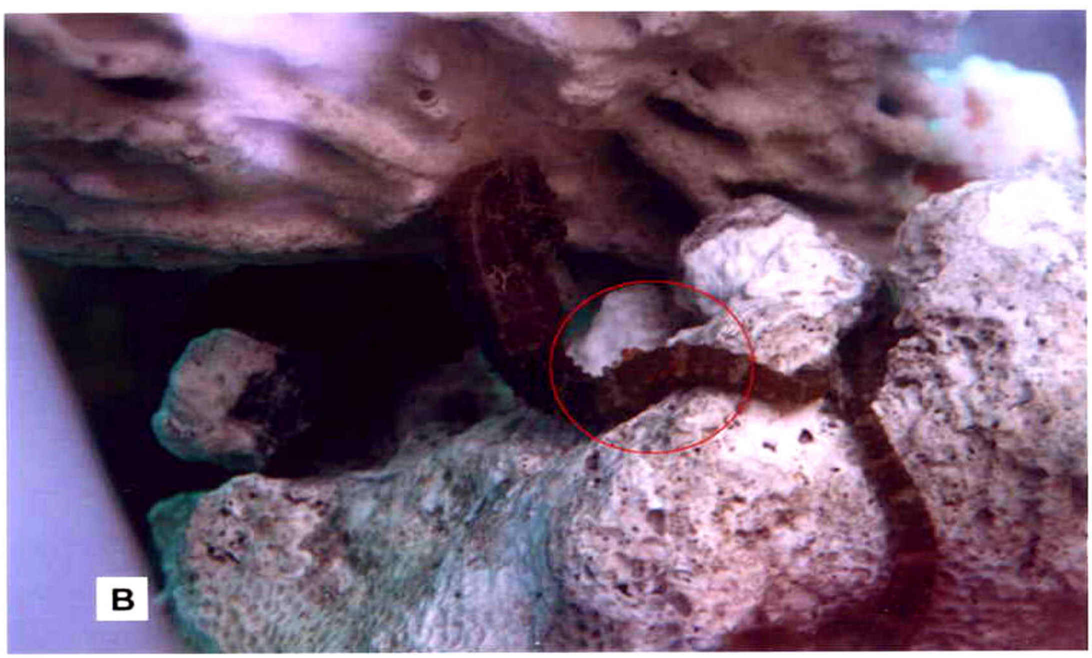


Male displaying 'readiness' to females

Plate 10



Female pointing



Hydrated eggs shed from female

4.9.4. Pumping

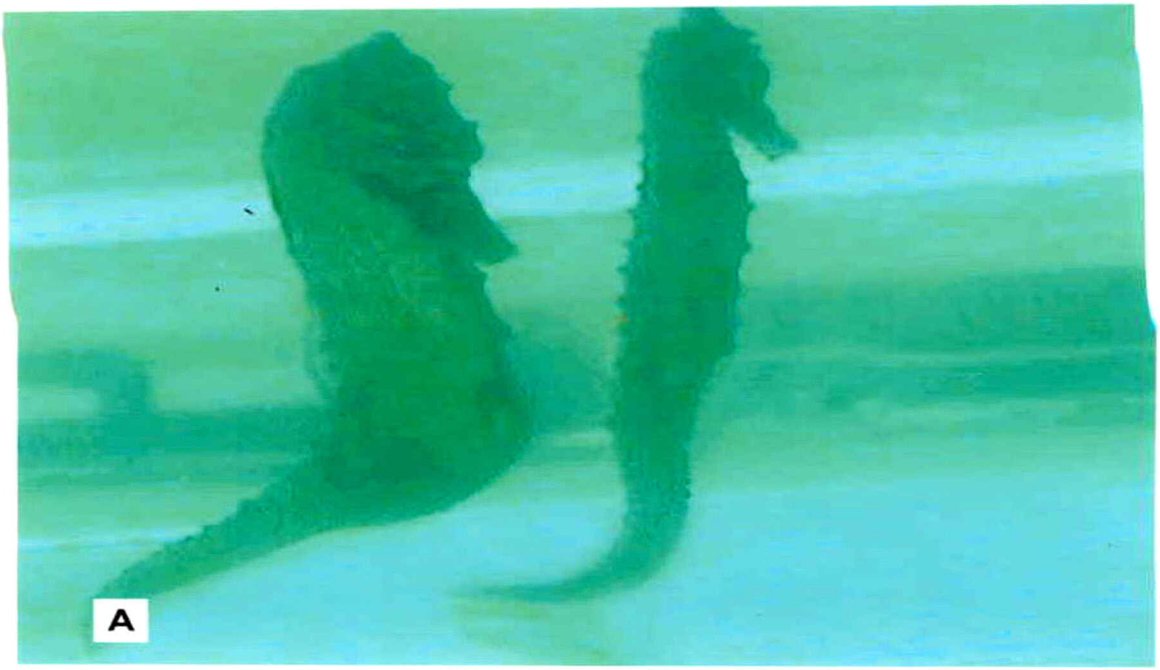
The next phase of courtship, on the day of mating was characterized by males assuming the pointing posture in response to female pointing (Plate 11 A) by displaying the pouch ready for reception. During this phase male and female initiated courtship by approaching equally often, and they tended to brighten simultaneously. The males generally responded to female points by pointing, by quivering, and by pumping. During the final courtship bout in this phase, males showed an increased tendency to female pointing by pumping. This courtship phase lasted more than an hour, consisting of 9 bouts, each lasting an average of 8 minutes.

4.9.5. Rising and mating

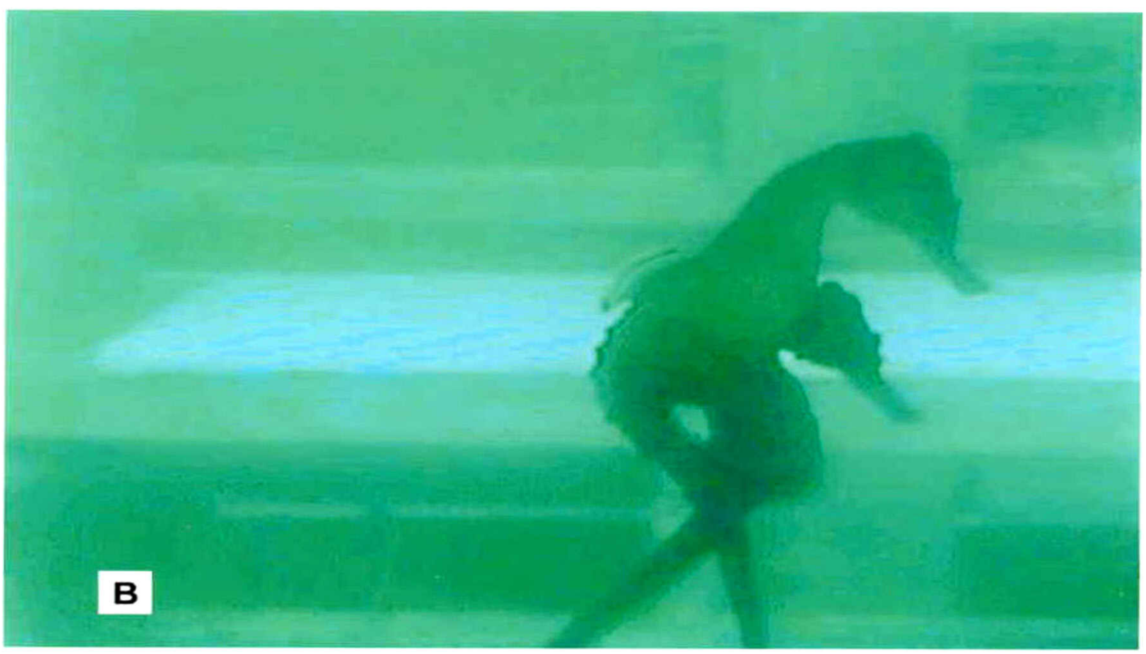
The final courtship phase was characterized by rising (Plate 11 B) in which both male and female rose upward together in the midwater column. Males responded to female pointing by either pointing or more often by pumping (Plate 12 A). Females became increasingly active in courtship in this phase. The first rise consisting of a male and female moving upward in the water column together was initiated by females more often than that by males. During the final copulatory rise (Plate 12B, 13 A&B), the female inserted her ovipositor and transferred the eggs through the opening into the male's brood pouch (Plate 14 A&B), which lasted for about 20 seconds. This phase ended after copulation, and the female swam down (Plate 15 A&B) to a hold fast, and the male, at first, settled on to the bottom of the tank, remained there for 3 minutes, and then moved to a different holdfast, still brightened, and swaying back and forth. After a few minutes the male and female lost brightening and regained their normal body colour.

Among the 5 pairs of brood seahorses observed, the courtship of only four pairs culminated in mating. In the other pair, the courtship behaviour was not effective for mating, since either of the pairs did not respond to each other. In this case, when the male made the initial approach and brightening, none of the females brightened in response. The male alternatively approached every female for response, but in vein. The next day when one of the females became brightened first, and the male previously brightened responded by brightening and quivering.

Plate 11

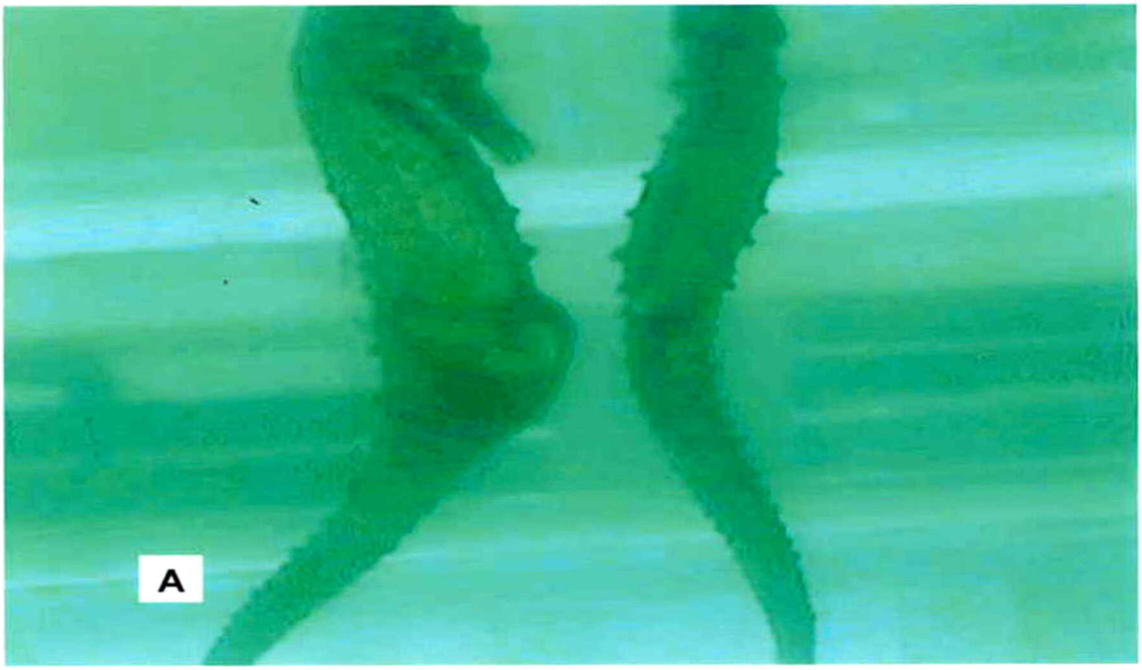


Male pointing

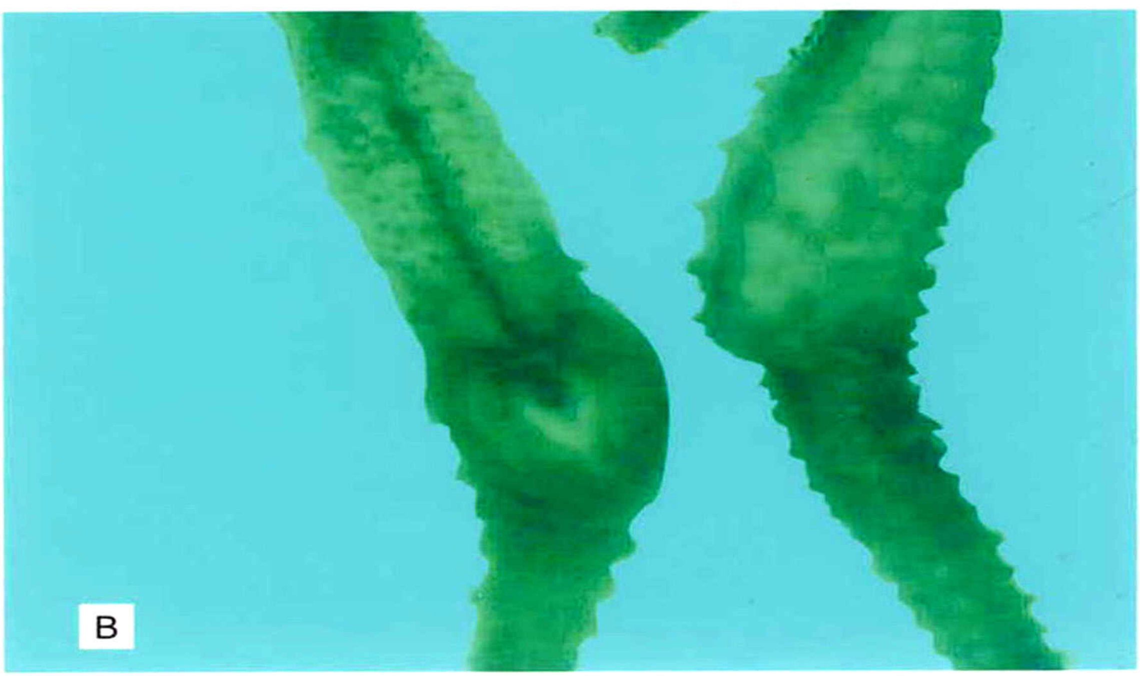


Male and female begin to rise

Plate 12



Male displaying pumping behaviour



Male and female come closer

Plate 13

A

Male opens brood pouch to receive the eggs

B

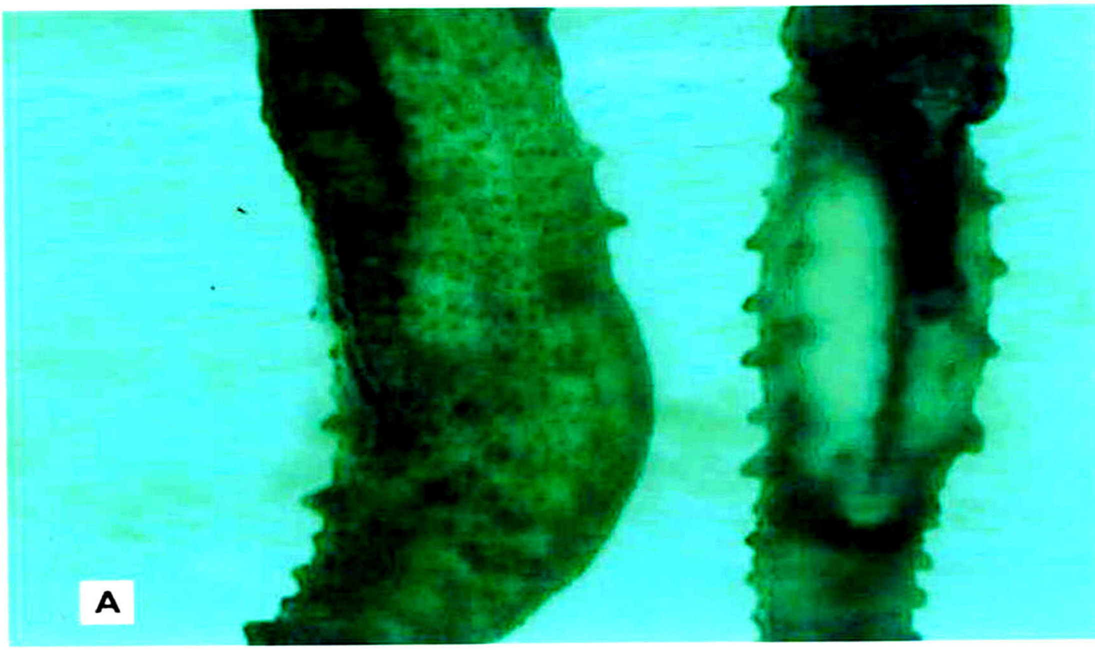
Male and female begin to lock in mid water

Plate 14

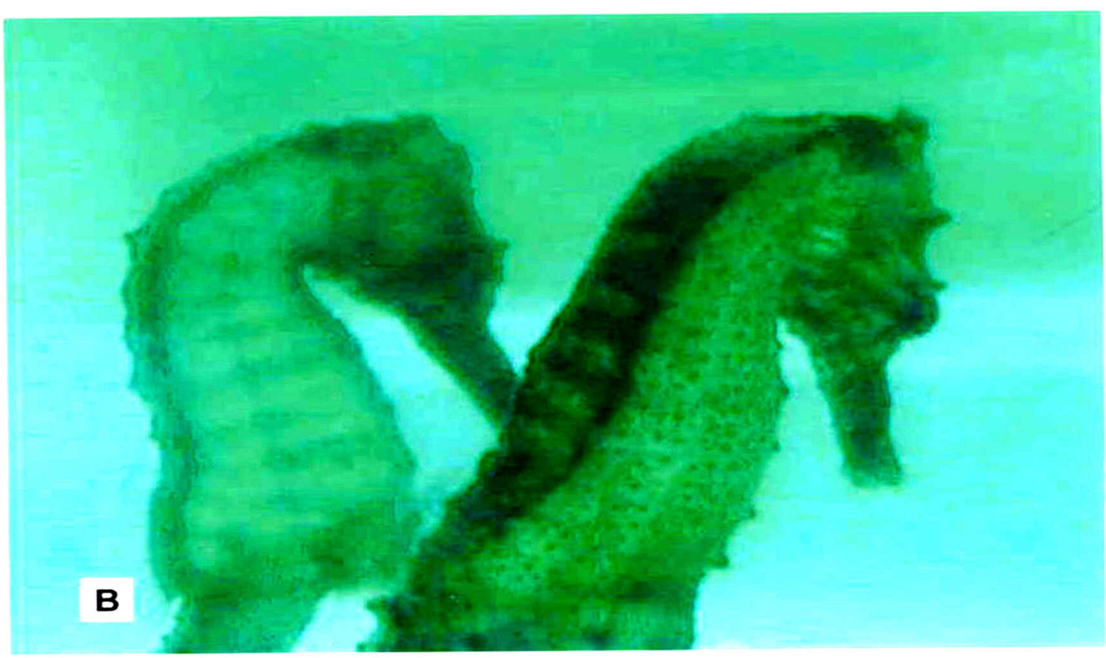
Mating and egg transfer

Mating and egg transfer

Plate 15



Male and female separate



Male and female begin to descend

But none of these courtship behaviours culminated in mating, although pumping behaviour was noted in the male in response to female pointing. This pair was later discarded. Also the female carrying the ripe ova, but that could not find a compatible mate shed all her hydrated clutch of eggs in the tank. The eggs were first noticed as attached to its body (Plate 10 B).

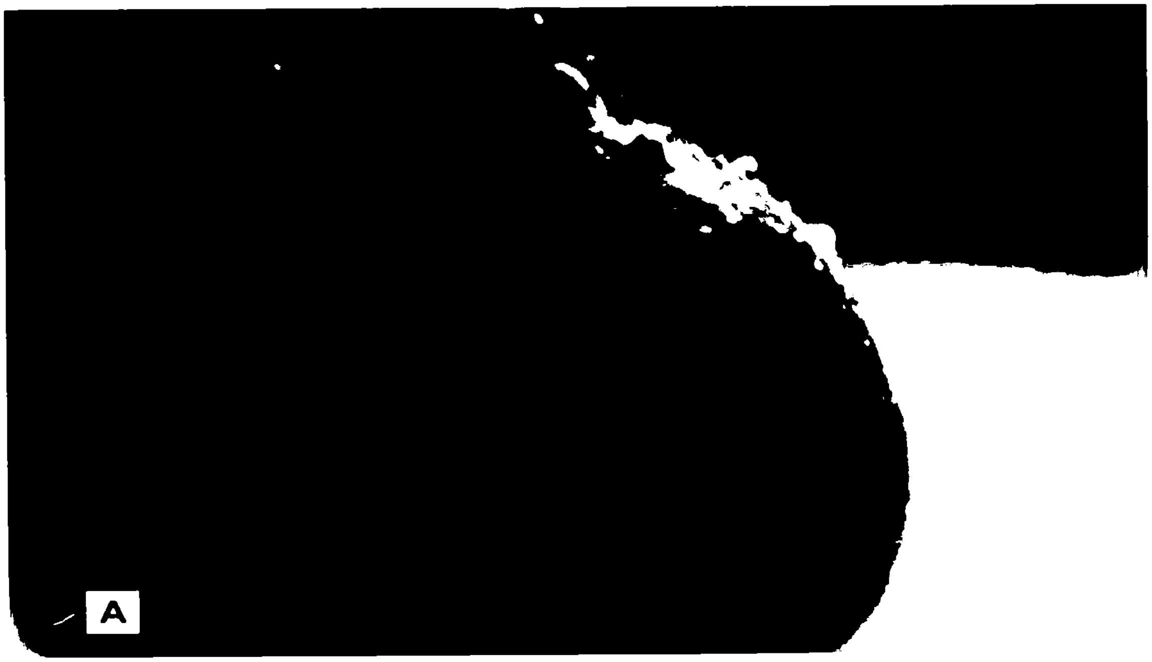
4.9.6. Male pregnancy

The male and female seahorses, after mating were kept in the incubation tanks. The brood pouch of the male remained swollen and heavy (Plate 16 A), but it was as active as before. The pair displayed daily greeting rituals in which they come together every morning soon after dawn, and displayed behaviour similar to those during courtship. The male and female were brightened; with their tails entwined they exhibited the first few movements of courtship. At times they remained holding around a common hold fast, and often moving apart, and coming together again to repeat the movements without holding onto the hold fast. These daily rituals lasted 12-15 minutes daily. The female finally left the male and the pair remained apart for the rest of the day. The male pregnancy period took 18-20 days in the present study.

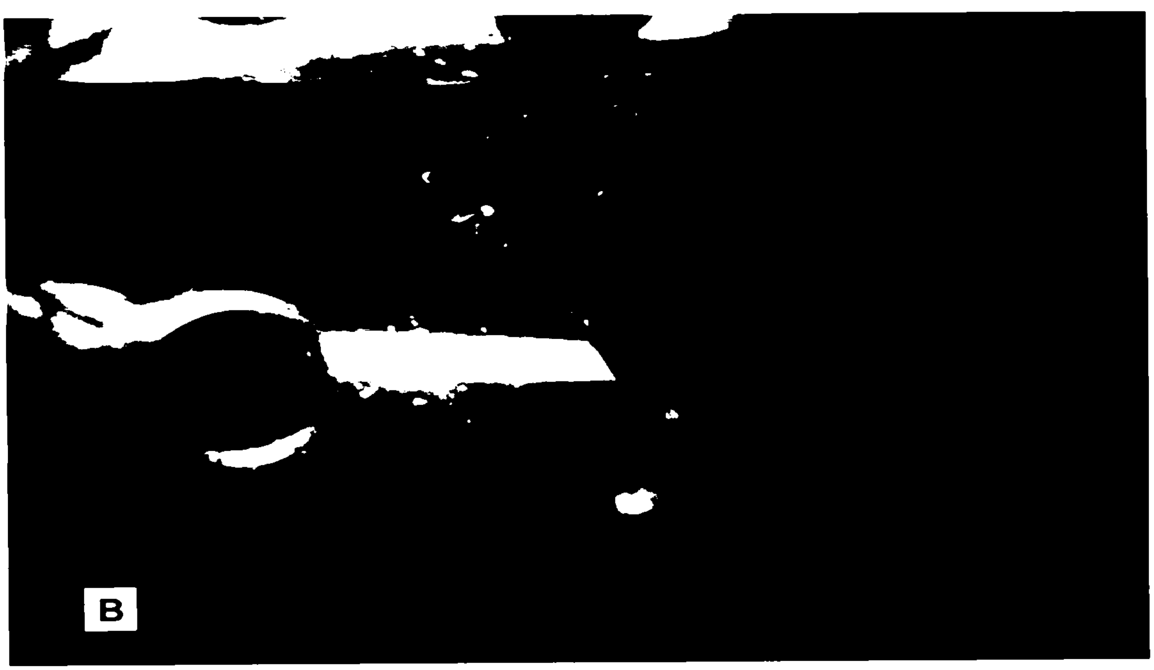
4.9.7. Parturition

The brood pouch of the male had swollen to a big size during the period of the pregnancy. Shortly before the discharge of the young, the pouch became nearly spherical in shape. So great was its distension that it appeared as though it would burst (Plate 17 A). The whole process of delivery of the young ones took about 3 minutes amid labour-like contortions of the male. The labour movements included a forward bending into a position of cramp followed by a rapid backward bend with an ejaculatory movement (Plate 16 B). This snapping back distended the brood pouch to such an extent that its orifice became virtually circular in outline (17 B & 18 A). The hatchings left the pouch generally with explosive spurts, accompanied by a flow of fine fragments, as the pouch slightly contracted. At intervals, the male seemed exhausted and drooped quiescently to an almost horizontal position (Plate 18 B). After the last young seahorse was expelled, the brood pouch returned to near normal proportions in about 5 minutes, and had completely subsided

Plate 16



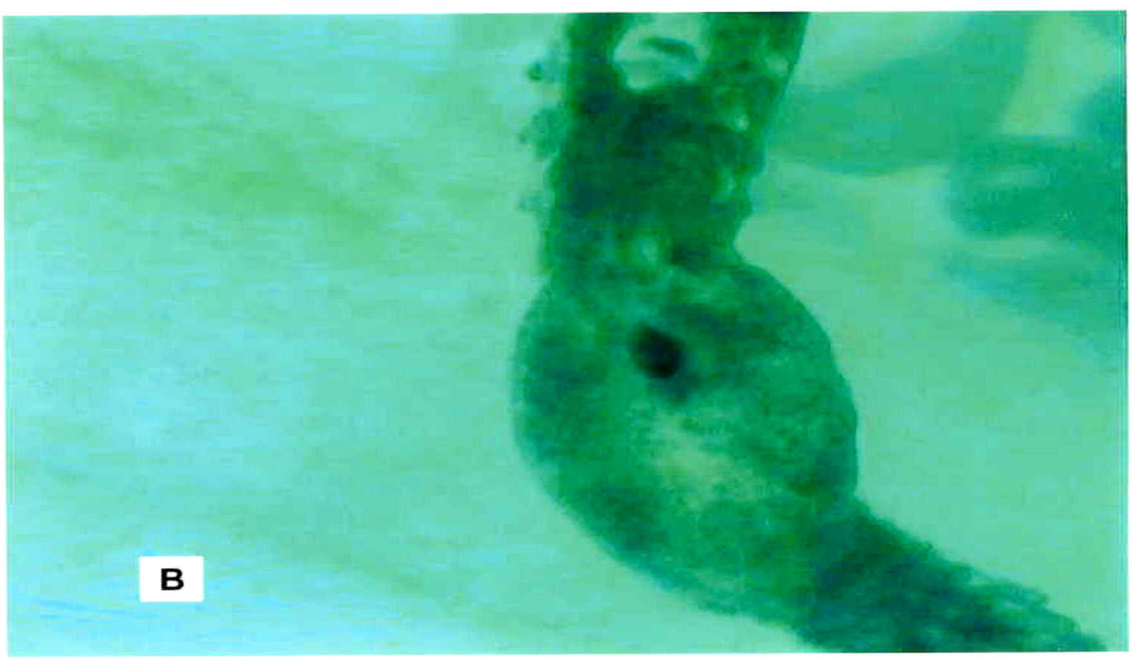
Inflated brood pouch of a male ready for delivery



Male releasing the young ones

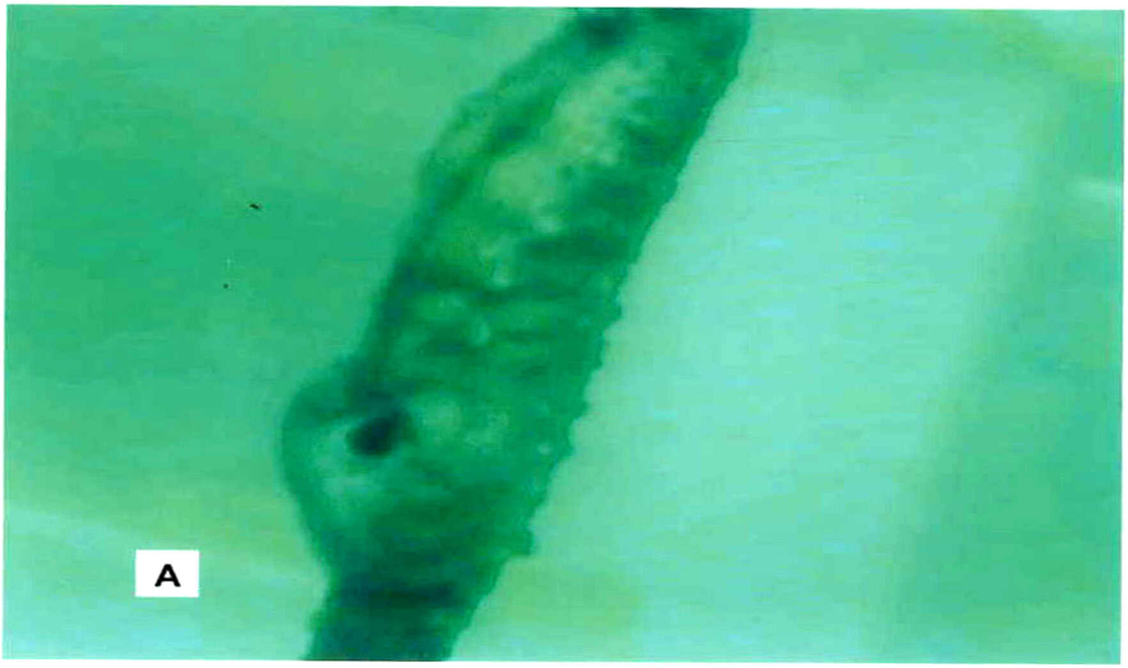
Plate 17

Male pouch, swollen and heavy



Male pouch opening

Plate 18



Male pouch opening to release young ones

Male exhausted after delivery

after an hour. The male was moving in mid water column, with the spurting movements, and not attached to any hold fast during the period of delivery of the young.

4.9.8. Hatchlings

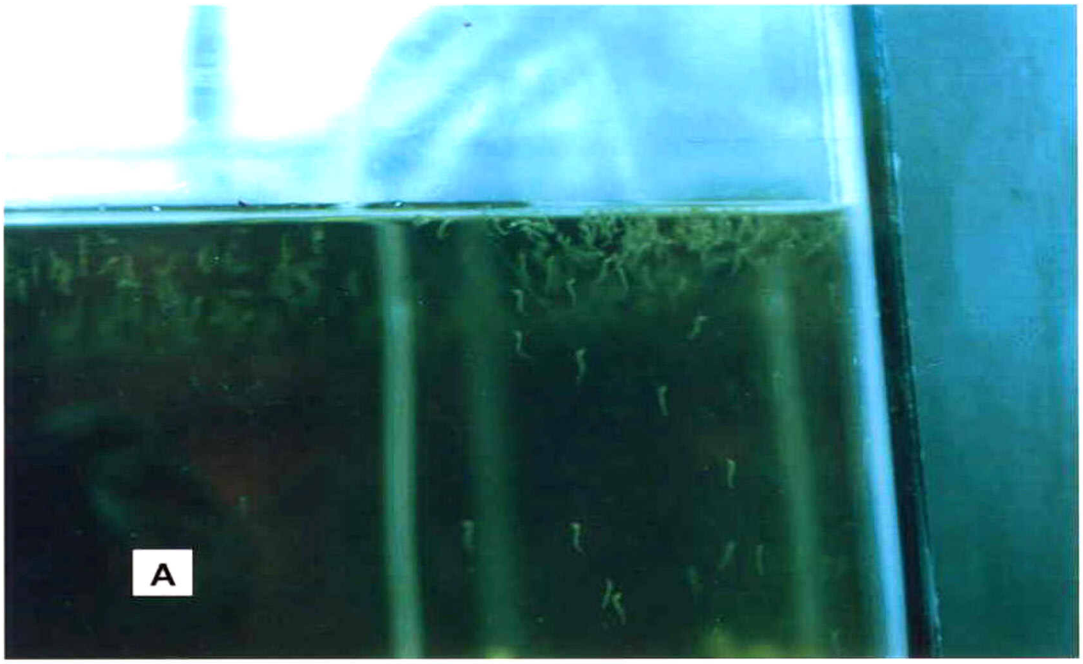
The newly born young of *H. kuda* ejected out from the brood pouch of the male raised to the water surface with its head inclined upwards (Plate 19 A), and touched the water surface at one go, and gulped in air to fill its bladder. They were pelagic, free swimming and miniature adults ranging in size from 7 - 8 mm. The body colour of the juveniles differed widely even within the same brood. Most were blackish, except a few which were light coloured. They drifted in water, but mostly clustered just below the water surface, starting to feed actively soon after hatching. The hatching took place at night and early morning hours and in salinities ranging from 5 to 50 ‰, with no apparent difference in the time of hatching or the number of hatchlings obtained. The hatchlings actively fed on *Artemia* nauplii from the same day of hatching itself.

4.10. Rearing of hatchlings

4.10.1. Effect of feed or feed combinations

The results of the captive rearing studies of newly hatched young ones of seahorses using different feeds are provided in Table 10 and Fig 26. The highest mean survival of 56% was obtained up to 60 days of rearing in the second treatment (T_2) in which the young ones were fed with enriched brine shrimp nauplii, *Artemia*, and mixed marine copepods. This was followed by *Artemia* alone (T_1) with a survival of 43%. The treatment (T_3) in which *Artemia* and freeze-dried Cyclop-eeze were used, gave the lowest survival of 21% at the end of 60 days of rearing. The results of the length and weight measurements of the juveniles on 7^{th}, 14^{th} , 28^{th} and 60^{th} days of rearing on a diet of *Artemia* and mixed marine copepods (T_2) are given in Table 11 and Fig 27. The increase in size of the juveniles during different stages of rearing is shown in Plates 20 and 21. The juveniles attained a maximum growth of 49.4mm and 316.14mg after 60 days of rearing. The percentage growth from 7th to 60th day was computed as 99.1%. The mean daily weight gain was computed

Plate 19



The hatchlings rise to the water surface initially for gulping in air

The newly hatched young ones assembled near the water surface

Table 10. Mean percentage survival of *Hippocampus kuda* juveniles after 60 days of rearing on three feed combinations of enriched *Artemia* alone (T_1), *Artemia* + marine copepods (T_2) and *Artemia* + freeze-dried Cyclop-eeze (T_3)

D.O.C	Percentage survival											
	T_1				T_2				T_3			
	R_1	R_2	R_3	R_4	R_1	R_2	R_3	R_4	R_1	R_2	R_3	R_4
7	80	72	64	76	72	76	72	72	72	72	76	76
14	56	56	48	64	64	68	64	60	48	44	64	56
21	52	56	44	56	60	64	60	52	36	32	44	44
28	44	52	44	52	60	60	56	52	28	28	36	28
60	40	44	36	52	56	60	56	52	24	16	28	16

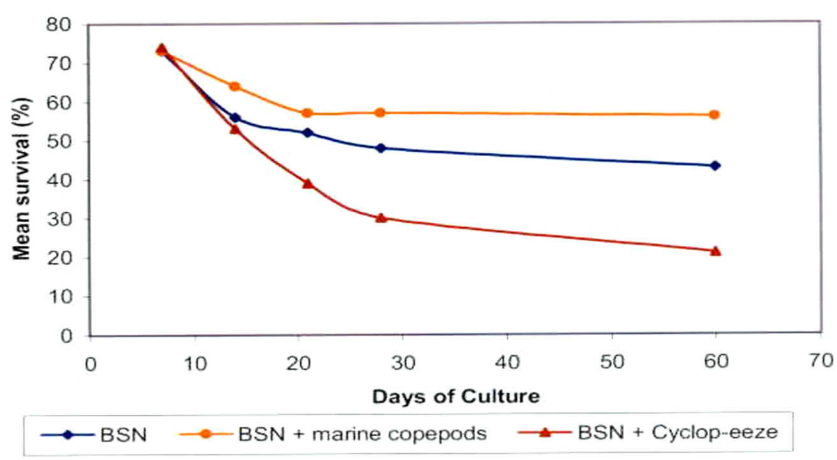


Fig 26. Mean percentage survival of 7 day old *Hippocampus kuda* juveniles after 60 days (post hatching) of rearing on three feed combinations of enriched *Artemia* nauplii (BSN) alone (T_1), BSN + marine copepods (T_2) and BSN + freeze-dried Cyclop-eeze (T_3)

Table11. Growth in length and weight attained by juvenile *Hippocampus kuda* after 60 days of rearing by feeding enriched *Artemia* and marine copepods

D.O.C	7		14		28		60	
Replications	L	W	L	W	L	W	L	W
1	1.20	0.0036	2.00	0.0278	3.10	0.0705	5.30	0.3712
2	1.10	0.0028	1.80	0.0189	2.90	0.0690	4.90	0.2985
3	1.20	0.0032	2.30	0.0287	2.80	0.0533	5.10	0.3300
4	1.00	0.0025	2.10	0.0246	3.20	0.0856	4.60	0.2760
5	1.20	0.0021	1.90	0.0199	3.50	0.0962	4.80	0.3050
Mean	1.14	0.00284	2.02	0.02398	3.10	0.07492	4.94	0.31614

D.O.C = days of culture
L = Length in cm
W = Weight in g

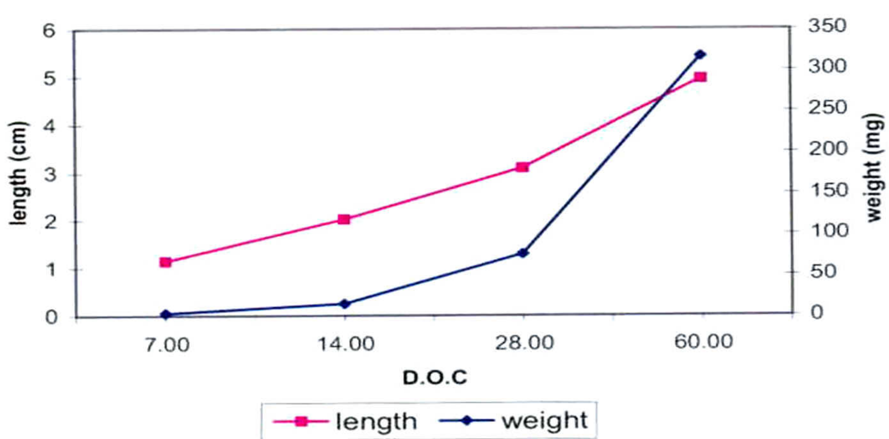
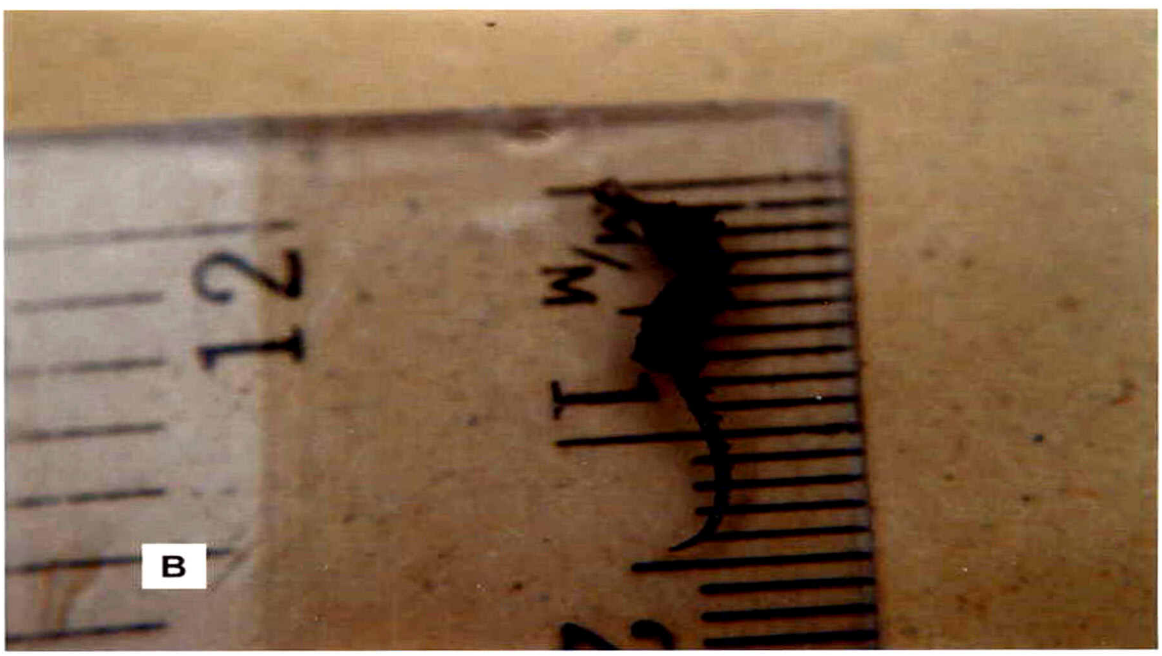


Fig 27. Growth in length and weight attained by juvenile *Hippocampus kuda* after 60 days of rearing by feeding enriched *Artemia* and marine copepods

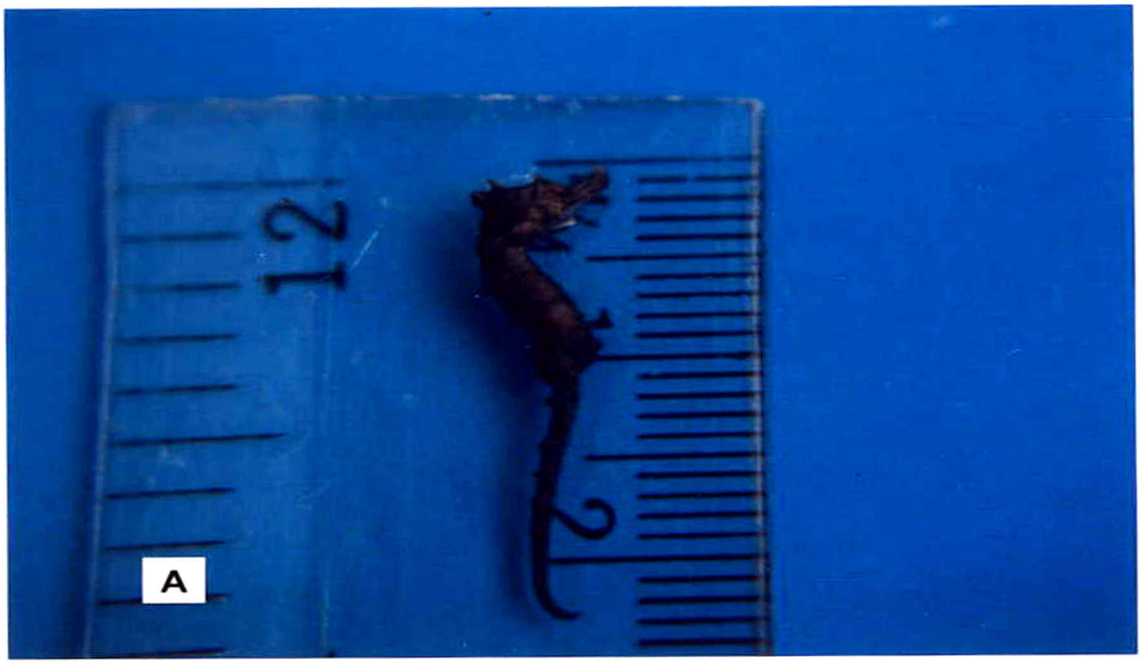
Plate 20

Hatchlings of *Hippocampus kuda* measuring 7mm



Juvenile *Hippocampus kuda* after 2 weeks of rearing

Plate 21



Juvenile *Hippocampus kuda* after one month of rearing

Juveniles of *Hippocampus kuda* reared up to two months as 5.91mg per day. The mean specific growth rate (SGR), which denotes the percentage increase in body weight per day for a period of 7 to 60 days of rearing, was determined as 8.89 %.

The ANOVA of the percentage survival (after making angular transformations) indicated that the treatments had significant effects ($P<0.05$) on the survival of seahorse hatchlings, except on the first and second weeks of rearing (Table-12). Pair wise comparison using 't' test revealed that the three feed combinations were significantly different except during the first seven days of rearing. Thus it could be inferred from the results that the second treatment (using enriched *Artemia* and marine copepods), which gave the highest mean survival of 56% after 60 days of rearing was the best feed combination for rearing the *H. kuda* juveniles. From the results it can be seen that in all the three treatments, the survival rate of the hatchlings up to 7 days were almost the same. The highest decline in survival occurred during the first 7 days of rearing.

4.10.2. Effect of stocking density

The results of the experiment to determine the optimum stocking density for rearing the juveniles of *H. kuda* are presented in Table 13, Fig 28 and Fig 29. The mean survival of the juveniles reared for 60 days under the six treatments of stocking densities were highest (52.59%) at a density of $2L^{-1}$, whereas $3L^{-1}$ gave the maximum production per litre. The highest mean increment in length was obtained at 1 L^{-1} (44.5 mm), followed by 2 L^{-1} (44 mm), $3L^{-1}$ (43.67 mm) and 4 L^{-1} (39.33 mm). The highest mean increment in weight of the juveniles was obtained at 2 L^{-1} (318.8 mg), closely followed by 1 L^{-1} (314.87 mg), 3 L^{-1} (312.83 mg) and 4 L^{-1} (300.07 mg).

The analysis of variance of the data (Table-14) showed that the stocking densities tested had significant effects ($P<0.05$) on the survival rates and growth in length and weight of *H. kuda* reared under captivity. Pairwise comparison using 't' test revealed that the densities of 5 $L^{-1}$and 6 L^{-1} had significantly lower survival and growth compared to all other treatments. The densities of 1 L^{-1}, $2L^{-1}$ and 3 L^{-1} were identical in the percentage survival and growth in length, whereas in the case of growth in weight, only the densities of 1 L^{-1} and 2 L^{-1} were identical, and all other treatments were significantly different from one another.

Table 12. Analysis of variance showing the effect of three different feed combinations of enriched *Artemia* alone (T_1), *Artemia* + marine copepods (T_2) and *Artemia* +freeze-dried Cyclop-eeze (T_3) on the survival and growth of the juveniles of *Hippocampus kuda* reared for 60 days

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Between feed combinations	0.978467	2	0.489233	0.063212	4.256492
Error	69.656300	9	7.739589		
Total	70.634767	11			

Pairwise comparison (7days) Critical difference: 3.18

Feed combinations	T_3	T_1	T_2
Treatment means	59.36	58.82	58.71

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Between Groups	88.5350	2	44.2675	2.980615	4.256492
Within Groups	133.6662	9	14.8518		
Total	222.2012	11			

Pairwise comparison (14 days)

Feed combinations	T_2	T_1	T_3
Treatment means	53.15	48.47	46.75

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Between Groups	277.2401	2	138.62000	13.132780	4.256492
Within Groups	94.9974	9	10.55527		
Total	372.2375	11			

Pairwise comparison (21 days)

Feed combinations	T_2	T_1	T_3
Treatment means	50.21	46.15	38.61

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Between Groups	522.8189	2	261.409400	43.56767	4.256492
Within Groups	54.0007	9	6.000078		
Total	576.8196	11			

Pairwise comparison (28 days)

Feed combinations	T_2	T_1	T_3
Treatment means	49.04	43.85	33.18

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Between Groups	937.9729	2	468.9864	38.04207	4.256492
Within Groups	110.9529	9	12.3281		
Total	1048.9258	11			

Pairwise comparison (60 days)

Feed combinations	T_2	T_1	T_3
Treatment means	48.46	40.95	27.11

** Underscored means are not significantly different (P>0.05)

Table 13. Effect of different stocking densities on the survival and growth in length and weight, of the juveniles of *Hippocampus kuda* reared for 60 days

Stocking density	Survival %	Production per litre	Increment in length (cm)	Increment in weight (g)
	51.11	0.51	48.00	0.31490
1/l	53.33	0.53	42.50	0.31480
	48.89	0.49	43.00	0.31490
Mean	51.11	0.51	44.50	0.31487
	46.67	0.93	43.00	0.31470
2/l	52.22	1.04	44.00	0.31500
	58.89	1.18	45.00	0.32670
Mean	52.59	1.05	44.00	0.31880
	51.11	1.53	42.00	0.31510
3/l	49.63	1.49	43.00	0.31490
	50.37	1.51	46.00	0.30850
Mean	50.37	1.51	43.67	0.31283
	35.56	1.42	40.00	0.30150
4/l	36.67	1.47	39.00	0.30010
	37.22	1.49	39.00	0.29860
Mean	36.48	1.46	39.33	0.30007
	28.89	1.44	31.00	0.23650
5/l	29.33	1.47	29.00	0.25010
	30.80	1.53	33.00	0.23000
Mean	29.67	1.48	31.00	0.23887
	20.74	1.24	29.00	0.22120
6/l	17.78	1.07	31.00	0.21860
	23.70	1.42	28.00	0.21010
Mean	20.74	1.24	29.33	0.21663

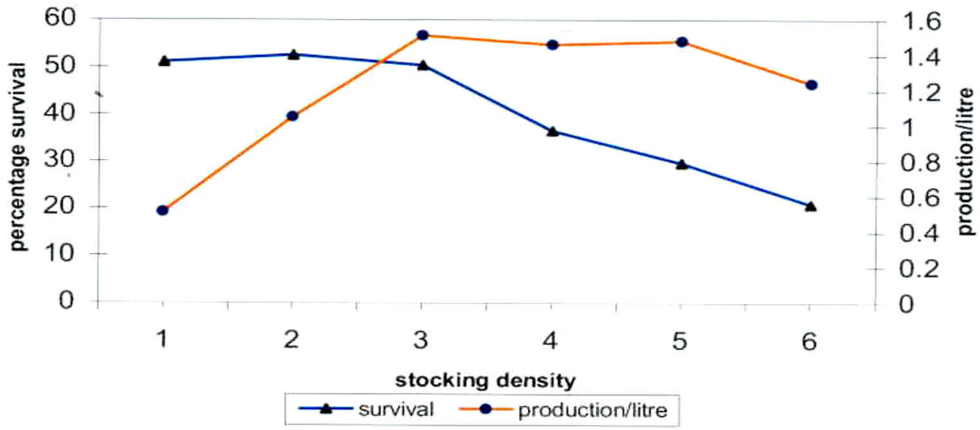


Fig 28. Effect of stocking density on the survival and production/litre of hatchlings of *Hippocampus kuda* reared for a period of 60 days

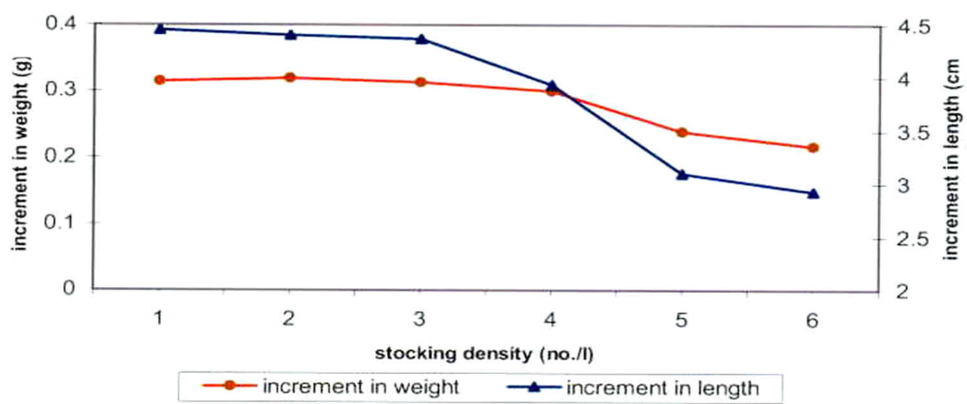


Fig 29. Effect of stocking density on the increment of growth in length and weight of the hatchlings of *Hippocampus kuda* reared for 60 days

Table 14. Analysis of variance showing the effect of different stocking densities on the survival rate and growth increment in length and weight of the juveniles of *Hippocampus kuda* reared for 60 days

Percentage survival

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Stocking densities	962.45127	5	192.49025	60.0369867	3.105874669
Error	38.474333	12	3.2061944		
Total	1000.9256	17			

Pairwise comparison **Critical difference: 4.30**

Stocking densities	T_2	T_1	T_3	T_4	T_5	T_6
Treatment means	46.49	45.64	45.21	37.16	33	27.05

Production per litre

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Stocking densities	0.37812	5	0.075624	60.3864786	3.105874669
Error	0.015028	12	0.0012523		
Total	0.393148	17			

Length increment

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Stocking densities	6.50625	5	1.30125	40.5584416	3.105874669
Error	0.385	12	0.0320833		
Total	6.89125	17			

Pairwise comparison

Stocking densities	T_1	T_2	T_3	T_4	T_5	T_6
Treatment means	49.50	44.33	41.00	39.33	31	29.33

Weight increment

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Stocking densities	28671.691	5	5734.3382	141.62551	3.105874669
Error	485.87333	12	40.489444		
Total	29157.564	17			

Pairwise comparison

Stocking densities	T_2	T_1	T_3	T_4	T_5	T_6
Treatment means	318.80	314.87	307.83	300.07	238.87	216.63

** Underscored means are not significantly different (P>0.05)

The production of juveniles per litre is an important consideration in the viability of a commercial hatchery operation. In the present study, although highest percentage of survival was obtained at the stocking density of 2 L^{-1}, the maximum production per litre (Fig. 28) was obtained at the density of 3 L^{-1} (1.5). The production per litre obtained was only 1.05 at 2 L^{-1}. Therefore, it can be inferred from the present study that a stocking density of 3 juveniles per litre is the optimum, which will give for early rearing of *H. kuda* the maximum production per litre, and significantly high survival rate and growth in length and weight.

4.10.3. Effect of salinity

The results of the experiment to determine the optimum salinity of rearing the juveniles of *H. kuda* for 14 days are summarised in Table 15, Fig 30 and Fig 31. A maximum survival of 60.56 % was obtained for 30 ‰, followed by 35 ‰ (59.23%), 25 ‰ (58.34%), 20 ‰ (55%), and 15 ‰ (53.89%). The lowest survival rates of 2.78% and 16.67% were obtained for 5 and 10 ‰ respectively. A maximum mean length of 28.7mm at 30 ‰ followed by 27.4 mm at 35 ‰ and 22.6 mm at 25 ‰ was achieved. The weights gained were identical at 30 ‰ (0.0391 g) and 35 ‰ (0.039 g), which were followed by 25 ‰ (0.0343 g). The mean length gained by juveniles reared at 15 and 20 ‰ salinity were similar (18.1 mm and 18.6 mm, respectively), whereas the weight gained was more for 15 ‰ (0.0295 g) than that for 20 ‰ salinity (0.0250 g).

The analysis of variance (Table 16) of the data on percentage survival, and growth in length and weight of the juveniles after a rearing period of 14 days has revealed that the salinity of rearing water had significant effect ($p<0.05$) on the survival and growth of the juveniles. Pairwise comparison using 't' test has shown that the salinities of 5 ‰ and 10 ‰ were significantly different from all the other salinities tested. There was no significant difference among 15 ‰, 20 ‰, 25 ‰, 30 ‰ and 35 ‰ tested, in terms of the percentage survival and the mean weight gained. However, the mean length of the juveniles reared in 5, 10, 15 and 20 ‰ were identical.

Table 15. Effect of different salinities on the survival and growth in length and weight, of the juveniles of *Hippocampus kuda* reared for 14 days

Salinity	Replicates	Survival %	Length (cm)	Weight (g)
5ppt	R_1	2.22	1.20	0.0020
	R_2	3.33	1.14	0.0026
	Mean	2.775	1.17	0.0023
10ppt	R_1	18.89	1.18	0.0080
	R_2	14.44	1.12	0.0098
	Mean	16.665	1.15	0.0089
15ppt	R_1	53.33	1.78	0.0298
	R_2	54.44	1.84	0.0291
	Mean	53.885	1.81	0.0295
20ppt	R_1	52.22	1.86	0.0260
	R_2	57.78	1.86	0.0240
	Mean	55	1.86	0.0250
25ppt	R_1	56.67	2.28	0.0327
	R_2	60	2.24	0.0359
	Mean	58.335	2.26	0.0343
30ppt	R_1	64.44	2.90	0.0383
	R_2	56.67	2.84	0.0399
	Mean	60.555	2.87	0.0391
35ppt	R_1	58.78	2.78	0.0390
	R_2	59.67	2.70	0.0389
	Mean	59.225	2.74	0.0390

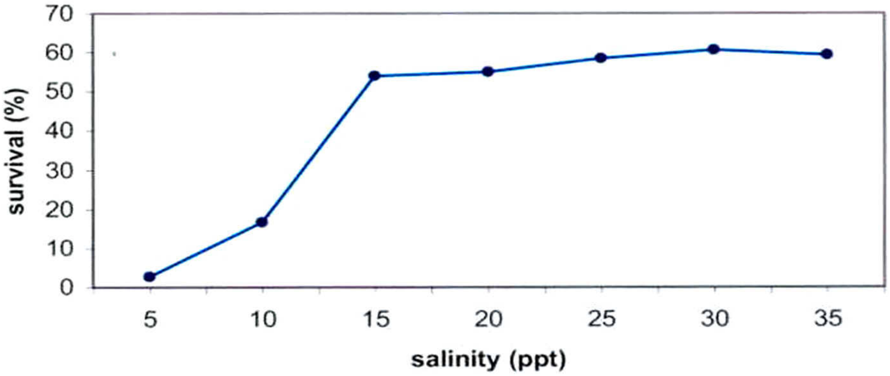


Fig 30. Effect of salinity on the percentage survival of the hatchlings of *Hippocampus kuda* reared for 14 days

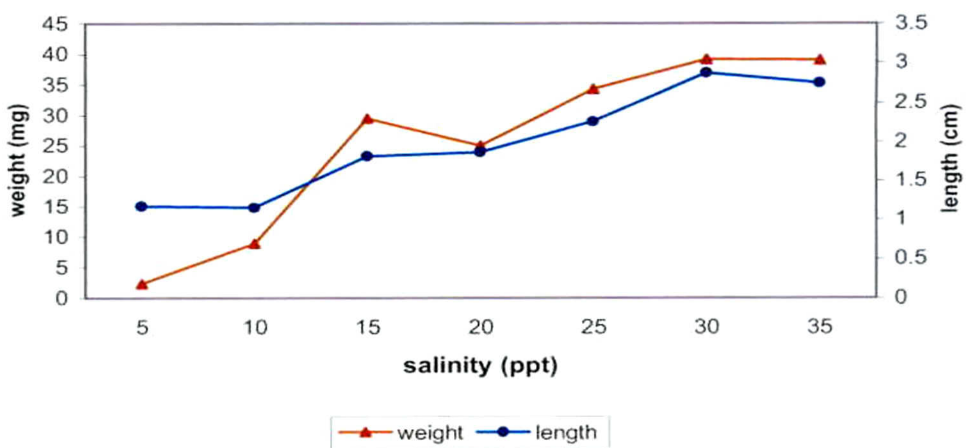


Fig 31. Effect of salinity on the growth, in length and weight of the hatchlings of *Hippocampus kuda* reared for 14 days

Table 16. Analysis of variance showing the effect of different salinities on the survival rate and growth in length and weight of the juveniles of *Hippocampus kuda* reared for 14 days

Percentage survival

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Salinities	3245.706	6	540.9511	148.1794	3.8659778
Error	25.55455	7	3.65065		
Total	3271.261	13			

Pairwise comparison **Critical difference: 12.71**

Salinities	T_6	T_7	T_5	T_4	T_3	T_2	T_1
Treatment means	51.11	50.32	49.8	47.88	47.25	24.05	9.54

Length

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Salinities	567.28	6	94.546667	590.91667	3.8659778
Error	1.12	7	0.16		
Total	568.4	13			

Pairwise comparison

Salinities	T_6	T_7	T_5	T_4	T_3	T_2	T_1
Treatment means	28.7	27.4	22.6	18.6	18.1	11.5	11.5

Weight

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Salinities	2545.83857	6	424.30643	284.2244	3.8659778
Error	10.45	7	1.4928571		
Total	2556.28857	13			

Pairwise comparison

Salinities	T_6	T_7	T_5	T_3	T_4	T_2	T_1
Treatment means	39.1	38.95	34.3	29.45	25	8.9	2.3

** Underscored means are not significantly different (P>0.05)

4.10.4. Effect of light

The results of the experiment to determine the influence of light to improve the early juvenile survival of *H. kuda* are given in Table 17, Fig 32 and Fig 33. The survival and growth in length and weight were the highest in the treatment T_2 where the rearing tank was partially covered from top. The maximum of 91% mean survival, and 36.2 mm and 0.06614 g mean length and weight, respectively were obtained in this treatment. These values were the highest of all the trials of rearing juveniles of *H. kuda* in the present study. In T_1 where the tanks were kept uncovered, the mean survival, mean length and weight were 55%, 21.4 mm and 0.303 g respectively. The mean weight of the hatchlings in T_3 had in fact come down from the initial weight of 18.6 mg and the feeding was very poor in the dark tanks.

The analysis of variance of the results has shown that illumination of the rearing tank had a significant effect ($P<0.05$) on the juvenile survival, and growth in body length and wet weight (Table 18). Pairwise comparison using 't' test has revealed that all the three treatments were significantly different from one another in relation to the percentage survival and growth in length and weight. Thus the second treatment (T_2) in which the rearing tanks were covered from the top leaving a gap of 10 cm from the bottom, so as to allow sufficient illumination for the tank, had the most favourable effect on the survival and growth.

4.10.5. Tolerance

The results of the study of the tolerance of 2 week old *H. kuda* juveniles to extreme levels of pH of rearing water are presented in Fig 34 and Fig 35. Juveniles tested for tolerance to a low pH of 4 died within 8 h of exposure. At pH 4.5, 85% were dead within 24 h. But at pH 6 only 20% mortality occurred within 24 h. Similarly at high pH of 11.5, 95% mortality occurred within 12 h, whereas only 20% were dead at pH 10 within 72 h. The LC_{50} values for the juveniles exposed to low pH were obtained as 4.62, 4.83, 5.43 and 5.56 for 12, 24, 48 and 72 h respectively. At the high levels of pH tested these values were 11.04, 10.52, 10.33 and 10.23 respectively. When the seahorse juveniles were transferred to the extreme levels of salinity and pH, they showed clear signs of distress by curling inwards, touching head and tail together instantly, and then stretching outwards. They then settled

Table 17. Effect of light on the survival, and growth in length and weight of the juveniles of *Hippocampus kuda* reared for 14 days

Treatments	Replicates	Survival %	Length (cm)	Weight (g)
T_1	R_1	57.5	2.20	0.0290
	R_2	55	1.90	0.0315
	R_3	50	2.10	0.0285
	R_4	55	2.30	0.0328
	R_5	57.5	2.20	0.0298
	Mean	55	2.14	0.0303
T_2	R_1	90	3.60	0.0749
	R_2	87.5	3.80	0.0698
	R_3	90	3.60	0.0552
	R_4	92.5	3.50	0.0696
	R_5	95	3.60	0.0612
	Mean	91	3.62	0.06614
T_3	R_1	12.5	1.10	0.00129
	R_2	7.5	1.00	0.00190
	R_3	15	1.10	0.00186
	R_4	10	0.90	0.00138
	R_5	15	1.00	0.00146
	Mean	12	1.02	0.00158

T_1 = open tanks
T_2 = partially covered tanks
T_3 = completely covered tanks

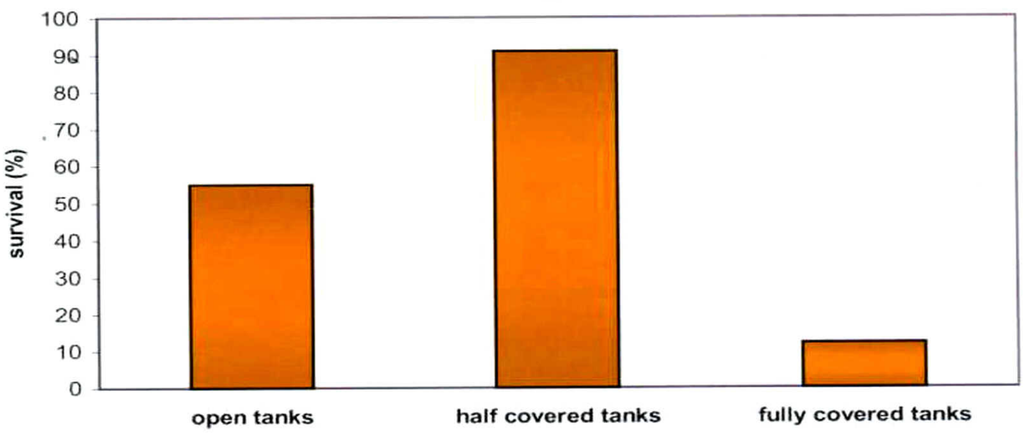


Fig 32. Effect of light on the survival of the hatchlings of *Hippocampus kuda* reared for 14 days

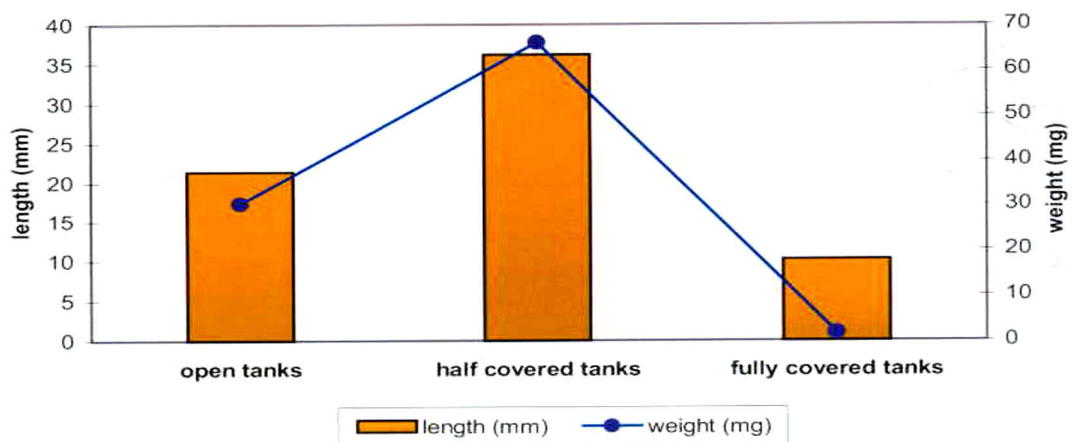


Fig 33. Effect of light on the growth, in length and weight of the hatchlings of *Hippocampus kuda* reared for 14 days

Table 18. Analysis of variance showing the effect of light on the survival rate and growth in length and weight of the juveniles of *Hippocampus kuda* reared for 14 days

Percentage survival

Source of Variation	*SS*	*df*	*MS*	F	*F crit*
Treatments	6925.477	2	3462.738	500.5754	3.88529
Error	83.0102	12	6.917517		
Total	7008.487	14			

Pairwise comparison **Critical difference: 2.78**

Treatments	T_2	T_1	T_3
Treatment means	72.73	47.87	20.12

Length

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Treatments	1700.8	2	850.4	607.4286	3.88529
Error	16.8	12	1.4		
Total	1716.6	14			

Pairwise comparison

Treatments	T_2	T_1	T_3
Treatment means	36.2	21.4	10.2

Weight

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Treatments	6735.017	2	3367.509	137.72	3.88529
Error	293.42	12	24.45167		
Total	7028.437	14			

Pairwise comparison

Treatments	T_2	T_1	T_3
Treatment means	66.14	30.32	15.17

** The three treatments are significantly different ($P<0.05$)

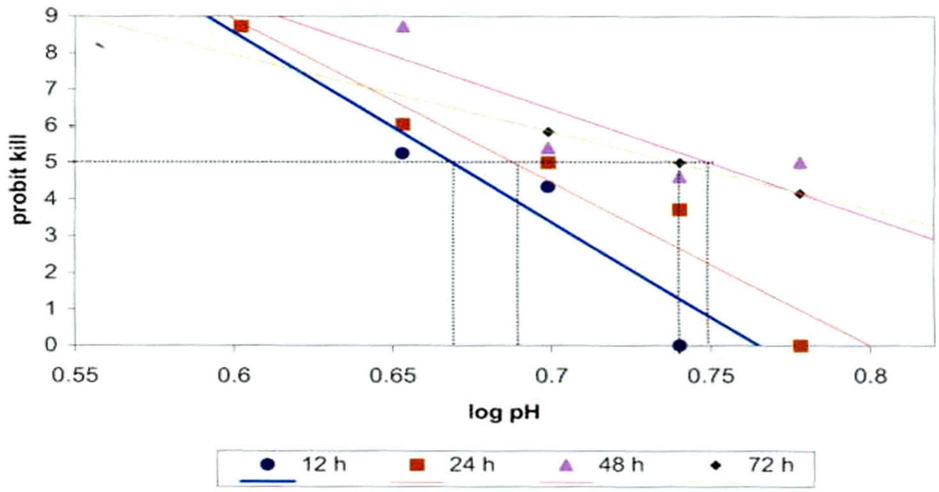


Fig 34. Tolerance of juveniles of *Hippocampus kuda* to low levels of pH

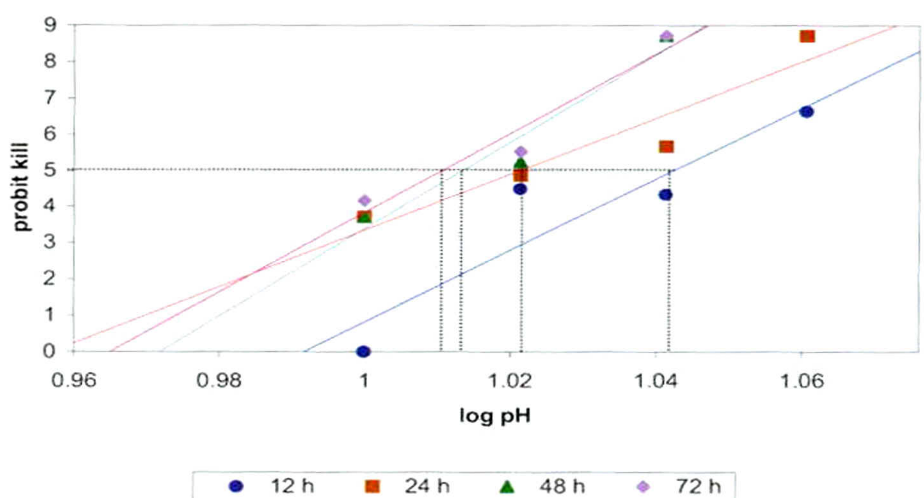


Fig 35. Tolerance of juveniles of *Hippocampus kuda* to high pH

to the bottom of the container for a while, and lied down on belly at the bottom of the tank; head up, with intermittent rising through the water column, swimming restlessly. Except in extreme ranges where the mortality was high, the juveniles became normal within a few hours. The results of the study on the tolerance limits of *H. kuda* juveniles to low and high salinity of water are depicted in Fig 36 and Fig 37 respectively.

The juveniles transferred to freshwater died within 10 h. At 1 ‰, 85% of the juveniles were dead within 12 h and 100% within 24 h. At 5 ‰ only 30% were dead within 72 h. In the case of higher salinities tested, complete mortality occurred within 12 h when the juveniles were exposed to 70 ‰ salinity. At 65 ‰, mortality up to 75% occurred within 12 h of exposure. However, only 10% of the juveniles were dead at 45 ‰ within 72 h. The LC_{50} values for low salinity were obtained as 1.59, 2.92, 3.63 and 4.67 ‰ at 12, 24, 48 and 72 hours of exposure, respectively. In the case of higher salinity levels tested, the corresponding LC_{50} values were 58.08, 54.45, 51.29 and 49.26 ‰ respectively.

The tolerance of the juveniles of *H. kuda* to formalin is depicted in Fig 38. The juveniles of *H. kuda* were found to have fairly high tolerance to formalin, unlike other fishes. The juveniles succumbed to a high concentration of 450 ppm of formalin within 12 h of exposure. Mortality up to 85% resulted upon exposure to 400 ppm formalin for 12 h. At 250 ppm only 20% mortality occurred up to 72 h. The LC_{50} values computed were 315 ppm, 296.48 ppm, 279.25 ppm and 271.02 ppm for 12, 24, 48 and 72 h respectively.

The water quality parameters (mean ± SD) in all the rearing experiments remained within the optimum range, as follows; temperature 29.2 ± 2.5^{0}C, pH 8.1 ± 0.6, dissolved oxygen 6.9 ± 0.8 ppm. The ammonia (NH_3-N) in water ranged from 0.025 to 0.08 ppm. The salinity of water in the rearing tanks, except in the experiment for optimum salinity, varied from 29 to 33 ‰. The experimental animals were transported in oxygen filled polyethene bags packed in cartons (Plate 22 A) from Mandapam. During the captive rearing experiments no serious disease problems were encountered in the seahorses maintained in glass tanks, except the kind of a fluid filled abscess / blister (Plate 22 B) that was presumed to have caused due to bad water quality.

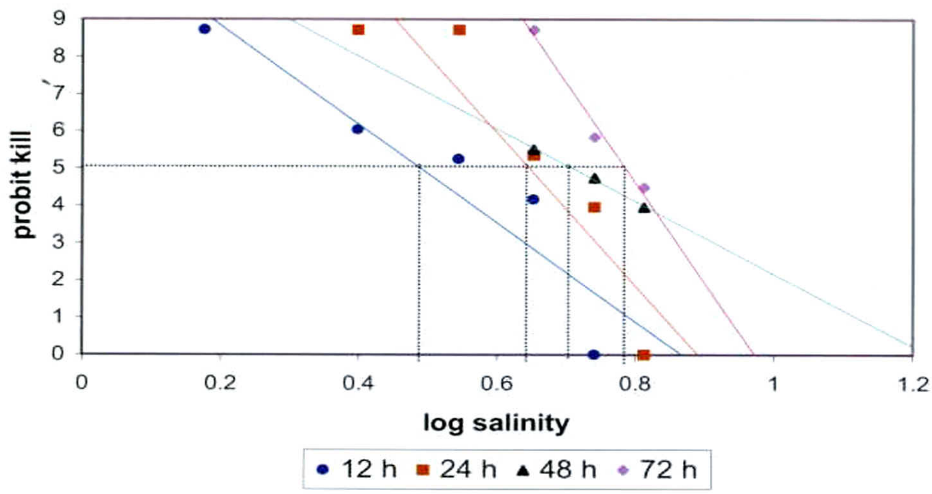


Fig 36. Tolerance of the juveniles of *Hippocampus kuda* to low salinity

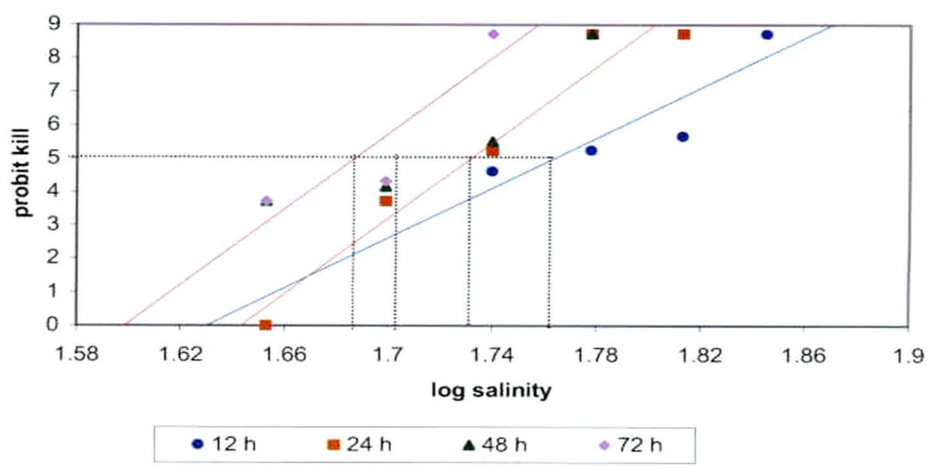


Fig 37. Tolerance of the juveniles of *Hippocampus kuda* to high salinity

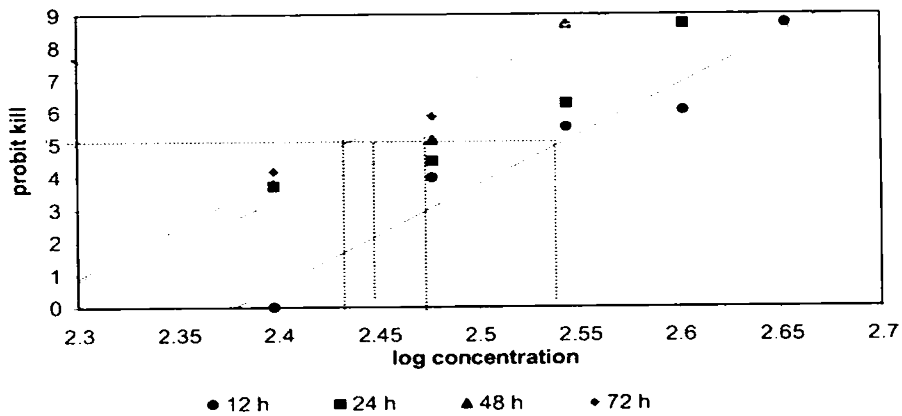


Fig 38. Tolerance of the juveniles of *Hippocampus kuda* to formalin

Plate 22

Seahorses packed live for transportation

An abscess / blister formed due to bad water quality

5. DISCUSSION

5. DISCUSSION

5.1. Seahorse catch and species composition

In India, an organised fishery and trade for seahorse existed only in the south Tamil Nadu coast, especially in Palk Bay and Gulf of Mannar. A major share of the catch originate from Palk Bay region, which might be due to the seagrass and seaweed habitat which is favourable for the occurrence of seahorses. The Gulf of Mannar is more or less rocky and offers a less suitable habitat for seahorses.

The results on the landings of seahorses from India revealed a considerable quantity that was caught in the year 2001. The total annual catch of dried seahorses of 9.75 MT was much above the only previous estimate of 3.6 MT by Vincent (1996) who relied on a brief trade survey alone to estimate the total catch. In the present study, actual landings from Thondi, the major collection area for seahorses in the Palk Bay coast were used to extrapolate the total landings. The percentage share of Thondi, Palk Bay and the Gulf of Mannar were fixed based on detailed interviews with the two major wholesale dealers of seahorses in Chennai, and many of the agents who collected seahorses from all the areas along the coast for supplying to the only two wholesale dealers in Chennai, through whom the total export of seahorses from India took place. In the present study, the catch from the major landing centre in India was also considered. Given the nature of the trade which involved many stake holders such as fishermen, boat owners, middle men and wholesalers engaged in a surreptitious trade, it was difficult to get precise idea or the exact quantity of the seahorses traded by interviews alone. This was emphasised by Vincent (1996) while estimating the catch from India to be 3.6 MT during 1995, and had mentioned that the actual figures would be higher. The exploitation of seahorses had been steadily growing in tandem with the increasing global demand, and the entire export of seahorses from India is concentrated at the Palk Bay coast, which contributed 76% of the total landings of seahorses in India. The major landing centre of the region Thondi, contributed 68% of the production from the southeast coast.

Based on field survey Vincent (1996) indicated that Palk Bay contributed 3040kg (84.44%) of the total annual seahorse trade of 3600 kg from the southern coast of India. But in the present study contribution of Palk bay was only

76%. After 1996, there was a steady increase in the quantity and value of seahorses exported from the country. India exported 2.35 MT of seahorses worth Rs. 15 lakh in 2000 reaching an all time high of 4.5 MT worth Rs. 27 lakh in 2001 (MPEDA, 2003). This figure is less than half of the present estimate of seahorse catch obtained in the present study. It might be due to the fact that much of the seahorse export from India were channelled through non-conventional means and therefore unrecorded. Since there is no significant domestic consumption of seahorses, most of the production would be exported by air shipment, which is often undeclared. The high demand and attractive price must have also increased the landing in other landing centres by attracting more fishing effort by fishermen for seahorses.

Marichamy *et al.* (1993) reported export of seahorses from Palk Bay as 300-400 kg month^{-1} in 1992, and Vincent (1996) reported that this might have reached 400-500kg by 1995, thus showing a steady increase in the monthly catch from 350kg to 450 kg over a period of 3 years. The average weight of the seahorses caught from Palk Bay was 2.5 g as reported by Vincent (1996). But in the present study the average dry weight obtained was 3.68g. This shows an increase in quantity and size range of seahorse caught from Palk Bay during 1996 to 2001. This might be due to the conservative estimates arrived from a small quantity of the samples, surveyed for a short period by Vincent (1996) or the improved efficiency achieved by the fishermen in dive fishery, or by extending the fishing zone to a wider area benefited from the high demand and increased price for seahorses.

The present study showed that there are at least six species of seahorses, which is more than that has previously been reported from India by Vincent (1996), who based on trade surveys had identified two species namely *H. fuscus* and *H. trimaculatus*, and referred to probably a third species thought to have originated from Kerala. However, it was based on a preliminary market study, and Vincent (1996) suggested detailed investigation to confirm the species composition.

Lourie *et al.*, (1999b) had reported at least seven species of seahorses from Vietnamese waters namely *H. spinosissimus, H. comes, H. trimaculatus, H. kuda, H. kelloggi, H. mohnikei and H. histrix.* Kuronuma (1961) had earlier cited only two species namely *H. kuda* and *H. histrix*, from Vietnam, and Nguyen Khae Huong

(1993) had reported five species namely *H. histrix, H. trimaculatus, H. kuda, H. kelloggi* and *H. japonicus* in the Gulf of Tonkin.

The measurement protocol described by Lourie *et al.* (1999a) was followed in the present study so that the results of the taxonomic studies would be comparable. Morphological variation was sufficient to distinguish the six seahorse species identified. The characters, which permitted the identification of species by eye, were mostly relied upon, so that it would facilitate practical application of these results in the field, and in markets to permit estimates of trade volumes and understanding of trade routes. Three species of seahorses appeared to be particularly common and widely distributed in India, *H. borboniensis*, *H. spinosissimus* and *H. kuda*. These species occur in a majority of landings from the southeast coast, mostly from the target catch by divers. Along the Palk Bay coast, the shrimp trawl by-catch brought *H. trimaculatus* in great quantities. The species from Kerala coast mostly comprised of *H. trimaculatus* followed by *H. borboniensis*. This confirms with the observations of Vincent (1996) that the trawl by catch from the south Tamil Nadu coast consisted of *H. trimaculatus.* Thus it can be inferred that *H. trimaculatus* is a species mostly occurring in deep waters. Further, almost all the landings of seahorses in Kerala came from shrimp trawlers, as by catch. The other major species along the southeast coast were collected from shallow depths of 3-3.5m or up to 10-13m, by divers using small country crafts.

Lourie (2000, pers. comm.) had indicated the occurrence of *a* big sized species probably *H. kelloggi* in India, particularly obtained from Kerala. Vincent (1996) had also reported a bigger species other than *H. fuscus* and *H. trimaculatus* that had been fished from Kerala. However, in the present study, *H. kelloggi* could not be identified from the specimens investigated. Although, a morphotype (Plate 5 B) similar to *H. kelloggi* in most characters was distinguished, it lacked the major feature of 39 or more number of tail rings. This single difference has made it to be grouped under doubtful morphotypes, which is yet to be identified. Also the seahorses available from Kerala were found to be of relatively small size, compared to those from Tamil Nadu coast. During the trade survey however, almost all the traders reported that big sized seahorses originated from the Kolachel region, which is located close to Kanyakumari and Kerala. Thus it seems probable that the big sized seahorses reported by Vincent (1996) to have come from Kerala, might have in fact originated from the Kolachel region.

The present study revealed a significant landing of seahorses, though small in size, mostly *H. trimaculatus* and *H. borboniensis* from Sakthikulangara/ Neendakara coast in Kerala, as a by catch in trawlers. However, there was no organized fishery or trade on seahorse in this region. It might be due to the small sizes of seahorses landed or the emphasis being given more to the high valued shrimp obtained from trawlers. It was also difficult to segregate a few seahorses from the huge heaps of by-catch consisting of Squilla, trash fish, small crabs, molluscs etc.

The six species identified in the present apparently belong to three species complexes outlined by Vincent (1996). *H. borboniensis, H. kuda* and *H. fuscus* belong to the *H. kuda* complex, and there is every possibility that more new species would emerge from this complex upon more detailed studies, including genetic research. *H. spinosissimus* belong to the spiny seahorses that are grouped under the *H. histrix* complex, *H. trimaculatus* complex include smaller deep-bodied and smooth seahorses, and further investigations are recommended to outline any other species under this group, particularly *H. fishery* to have any representation in Indian waters. Lourie *et al.*(1999a) had also cautioned that some of the species described might still be complexes, containing more than one discrete species and that required further research, using morphometric and DNA sequencing data.

Considerable morphological variations existed in the *H. borboniensis* and *H. kuda* identified in the present study. It might be possible that such variability is due to developmental stages or environmental factors, but it needs more investigations to eliminate any other species between these two morphotypes investigated in the present study. *H. borboniensis, H. guttulatus* and *H. spinosissimus* had never been reported from India before. Four new morphotypes which were similar to some of the known species listed by Lourie *et al.,* (1999a), but lacking a few distinguishing characters, were also identified. Plate 5 A was very similar to *H. comes,* with double eye spines, but the cheek spine was double only on the left side. Plate 5B might be a variant of *H. kuda,* except the high columnar coronet like that of *H. camelopardalis* and *H. lichtensteinii.* Plate 6A looked similar to *H. sindonis* with double and unequal eye spines, but the trunk rings were 11 in number. Plate 6B had an elongated body and features similar to *H. kelloggi,* but it had only 34 tail rings, much less than the 39 tail rings for *H. kelloggi.* Based on the morphological characters, further investigations are required for providing them the status of a new species. Probably they would be at least three new species as evident from clearly distinguishable characters (Plate 5 & 6).

Lourie *et al.* (1999a) had suggested that the *H. kuda* complex warranted further research to clarify relationships among the species it encompassed. A number of specimens from Australia had better developed (but rounded and irregular) tubercles, low double cheek spines and darker or paler 'saddles' across their dorso-lateral surfaces. Similar-looking specimens had also been seen from Hawaii (Lourie *et al.,* 1999a). There is some genetic evidence in the case of Australian species that these specimens might be distinctly different from *H. kuda*, but further research was needed to determine whether they were indeed different species.

It was earlier reported by Marichamy *et al.* (1993) that the seahorses occurring the Tamil Nadu coast belonged to the species *H. kuda*. However, in the present study, the dominant species in the catch were found to be *H. borboniensis* and *H. spinosissimus* followed by *H. kuda.* Since at the beginning of the study, based on reports it was assumed that the dominant species was *H. kuda,* the experiments were aimed at studying the biology and larval rearing of that species. Hence it was followed, although *H. kuda* was not found to be the most dominant species. Moreover, *H. kuda* grows to a big size and is one of the most favoured species in trade owing to its smooth texture of the body (Vincent, 1996).

The measurement protocol is being relied upon worldwide to identify new species of seahorses based on morphological characters. Home (2001) had identified a new seahorse species, *H. queenslandicus* from northern Queensland, Australia. The diagnostic characters of this species included 10-11 trunk rings, 34-36 tail rings, 15-18 dorsal fin rays, 16-17 pectoral fin rays, and a moderately low coronet with five distinct spines. Golani and Fine (2003) reported the occurrence of *H. fuscus* for the first time in the Mediterranean, and observed that its presence there was probably due to migration from the Red Sea via the Suez Canal. Further studies that also encompass genetical evidence are therefore recommended to examine the characteristics of the other morphotypes to outline more species that might be present in the Indian waters.

Dried specimens were used in the morphometric measurements in this study. Lourie *et al.* (1999b) had reported that since seahorses have a rigid external skeleton of bony plates which permitted little change in shape and size, the morphometric results could be justifiably extrapolated to fresh specimens and hence be of use in identifying live seahorses. The main difference in live specimens might be the presence of skin appendages and encrusting algae, which might mask some of the body features, such as markings or spines. These appendages usually fall off soon after death (Lourie *et al.,* 1999b).

The average wet weight of the seahorse specimens from Thondi in the present study was obtained as 8.49±1.1g, while Marichamy *et al.* (1993) obtained mean wet weights of 7.86g and that for dried specimens as 4.2g. In the present study, the *H. trimaculatus* specimens collected from Sakthikulangara had mean weights of only 2.92±1.3 g.

5.2. Population dynamics

The lack of knowledge of their biology in the wild restrict the conservation assessment and management of seahorse populations. The lack of works on seahorse biology means that it is necessary to extrapolate from a few studies on single species to the genus in general. In view of the general pattern of seahorse biology, it can well be assumed that the seahorse behaviour and ecology is rather similar across species. The population dynamics of the seahorses are poorly studied. Anon (1990a) reported that the natural life span and mortality rates for seahorses (and the parameters that define them) are virtually unknown, and in need of research.

The analysis of length frequency data and the estimation of growth and mortality parameters in the present study could be correlated with the market observations. The asymptotic length (Lα) obtained for seahorses at Thondi (220.52mm) was in agreement with the highest sizes obtained in the market. However, conservative reports suggested that bigger sized seahorses (of 10-13" size) probably a separate species other than the six species listed in the present study were available from the Kolachel region of Tamil Nadu. These collection were sold directly the wholesale dealers at Tamil Nadu for export, and were not represented in the samples in the present study. Based on the sample, the probability of capture curve obtained indicated that most of the size classes were having an almost equal probability of occurrence in the catch. This might be because of the selective mode of fishing seahorses by raw divers who specifically target seahorses because of their ready market. However, the lower size classes were not being amply represented in the fishery, since they were low priced and not preferred.

The mortality parameters namely total mortality (Z), natural mortality (M) and fishing mortality (F) for the seahorse catch at Thondi in 2001 were obtained as 1.27 year $^{-1}$, 0.72 year $^{-1}$ and 0.56 year $^{-1}$ respectively. The exploitation rate (E=F/Z) obtained as 0.44 indicates that the seahorse stock at Thondi was relatively heavily exploited, suggesting nearly 44% of the mortality of seahorses to be due to fishing. Anon (1990a) reported that the longer-lived or slower-growing fish species tended to be more vulnerable to over-exploitation. Life span of a very small species, *H. zosterae* was only 1-1.5 years in Florida (Strawn, 1958), while for most medium sized Indo-Pacific seahorses, it was assumed to be 4-5 years, inferred from size distribution and captive observations (Vincent, 1996).

Natural adult mortality rates in seahorses were reported to be low based on tagging studies of *H. whitei* (Vincent and Sadler, 1995). Few predators appeared to target adult seahorses perhaps because of their bony plates and spines that make them unpalatable, and their camouflage and immobility that make them difficult to be detected (Lourie *et al.*, 1999a). Mortality is probably the highest in young seahorses (Vincent, 1996). There had also been evidences of several predators devouring seahorses (Jordan and Gilbert, 1882; Longley and Hildebrand, 1941; Herald, 1949; Strawn, 1958, Whitely and Allan, 1958). Fisheries management tends to invoke the general rule of thumb that the fishing mortality should be lower than natural mortality (Anon, 1990a), which was found to be true in the present study for seahorses at Thondi. However, the exploitation rate appeared to be relatively high implying a moderately heavy fishing.

5.3. Gut content analysis

The gut content analysis of *H. kuda* in the present study indicated that its food mainly consisted of crustaceans (almost 90%) such as copepods, isopods, amphipods and decapod larvae, and mysids. Most of the organisms in the gut had their original shape retained, enabling easy identification of the prey. This might probably be due to the peculiar feeding habit of seahorses in which they ingest the prey via a strong suction action down their tubular snout (Bergert and Wamwright, 1997). Since seahorses have no teeth and stomach (Rauther, 1925) the prey are swallowed whole and pass rapidly through the digestive system and they would eat anything that fits into their mouth (Vincent, 1996).

The predominance of epibiotic and epibenthic crustaceans in the diet of *H. kuda* is a reflection of the method of predation and habitat. In the southern coast, seahorses are abundant along the Palk Bay coast, which offers a suitable habitat for them, by means of a rich seaweed and seagrass environment. Copepods form one of the most dominant groups of marine plankton as they play an important role in the food chain of the marine ecosystem. Maruthunayagam and Subramaniam (2000) studied the diversity of copepods in Palk Bay and Gulf of Mannar, at mean depths of 10-12m. They collected 34 species of copepods in total, of which 29 were calanoids, 4 species were cyclopoids and one species was a horpacticoid. The calanoids contributed the bulk of copepods. This was also reflected from the results of the present study in which calanoids predominated the copepods in the gut content of *H. kuda*.

Reid (1954), Lovett (1969), Tipton and Bell (1988), and Texeira and Musick (2001) had also reported the dominance of seahorse diet by crustaceans. However, the importance of specific types of crustaceans in seahorse diets was reported to vary with prey availability and abundance, as well as the size of the seahorse species that consumes them. Tipton and Bell (1988) found that in the small seahorse *H. zosterae* harpacticoid copepods were the dominant prey item, with amphipods consumed to a much lesser extent and only more so in larger individuals. For larger seahorses, copepods would be a minor dietary component, with a greater amount of larger prey items such as amphipods, mysids, and caridean shrimp, up to 2cm in length. In the present study, however, calanoid copepods were predominantly observed, irrespective of the size of the seahorse. Also Svensson (1988) reported that among the pipefish relatives of seahorses, the pregnant males eat more plankton than other pipefishes, perhaps because they are too slow to chase larger prey, which is also likely to be true for seahorses.

Seahorse ingests their prey via a strong suction action down their tubular snout (Bergert and Wamwright, 1997). Seahorses are ambush predators who rely on stealth and camouflage to approach within striking reach of the prey, or allow their prey to move within striking range (Flynn and Ritz, 1999). Seahorses like most fishes also depend on vision in their search for prey (Guthrie, 1986) because they lack teeth and any masticatory organs, the prey items can generally be found intact, which greatly enhances the process of prey identification. This was also evidenced in the aquarium studies where intact *Artemia* nauplii given as feed, were noticed in the faeces of the juvenile *H. kuda*. Adult seahorses were observed in the laboratory to swallow even bigger sized prey such as the tiny freshwater prawns whole in one strike.

5.4. Maturity and breeding season

The breeding season of *H. kuda* in the present study was found to be June to August with the males attaining maturity in June at a size of 66.07 mm and females in August at a size of 77.99 mm. The size at first maturity of the males were comparable to the aquarium studies in which the juveniles were reared up to a period of 6 months when they developed the brood pouch at a size of 73 mm., indicating the onset of maturity. This size of first maturity was, however, higher than that was obtained for the males in the wild. The inadequacies in feeding under captive conditions might be one of the factors contributing to this difference. In the wild, seahorses have access to a wide array of food organisms whereas feeding was obviously limited in captivity. Also in the wild the seahorses are likely to have all the essential stimuli that would fine-tune the size and the season of attaining maturity. Vincent (1996) had reported that the length and timing of reproductive season of seahorses are influenced by the location, light, temperature and turbulence from monsoon rains and high winds. Strawn (1958) also observed that the sexual maturity was dependent on temperature in the male pygmy seahorse *H.* zosterae in Florida, where the males attained maturity during summer in less than three months and 16 mm, unlike in winter when it took three months and 20 mm length. However, Strawn (1958) could not find the temperature to correlate closely with the beginning and end of the breeding season in the case of *H. zosterae*.

Lourie *et al.* (1999a) also reported that species like *H. comes*, *H. erectus*, *H. fuscus*, *H. guttulatus*, *H. hippocampus* and *H. whitei* appeared to be mature at six months to one year. Females also matured at the same size as that of males, but physical manifestation was less obvious (Lourie *et al.*,1999a).

In the landing of seahorses at Thondi, males with carrying brood pouch were obtained throughout the year, at least in small quantities during the lean seasons of catch. This indicated that most of the species of seahorses or at least some of them are year-round breeders at Thondi. The peak season of seahorse availability was also marked with the maximum landing of the males with fully laden brood pouch, which progressively reduced after September, but still being present during all the subsequent months. Hence it could be reasonably assumed that the months of June, July and August are the peak breeding season of seahorses. This was also confirmed by the peak average Kn values obtained for the male and female seahorses during these months. Seasonal pattern in seahorse behaviour are apparent in temperate species like *H. whitei* in Australia which has a distinct breeding season, usually lasting about six months in the summer (Vincent and Sadler, 1995; Boisseau, 1967a). They disappear from their inshore breeding grounds during the winter and are believed to spend time in deeper waters. Reproduction in tropical species, however, is commonly influenced by rainy seasons. For instance *H. fuscus* breeds at different times of the year on the east and west coasts of Sri Lanka, according to the timing of the monsoons (Lourie *et al.*, 1999a), although *H. comes* in the Philippines appears to breed all the year round regardless of rains (Perante *et al.*, 2002). In Thondi also the fishery is concentrated around the peak breeding seasons, even though the seahorses are available throughout the year.

The increased incidence of carrying males in the landings of Thondi during the peak breeding season could also be an indication of the vulnerability of pregnant males to heavy fishing. Males of most species apparently move less than females, perhaps because they are often heavily laden with embryos (Lourie *et al.* 1999a). Seahorses also generally have limited mobility and home ranges.

Seahorse fecundity is lower than that of most fishes taken by large-scale fisheries (Vincent, 1996). The fecundity of female *H. kuda* in the present study ranged from 658 to 823. However, the hatch fecundity was only 328-495 hatchlings. The hatch fecundity of *H. kuda* obtained in the present study was higher than those reported by Vincent (1996) of 100-200 young per pregnancy. This might probably due to the bigger size of the seahorse *H. kuda* under study. Anil *et al.* (1999) obtained 192 hatchlings and 292 premature embryos spawned in aquarium tanks. In the case of a third seahorse only 56 hatchlings were obtained. However, Ignatius *et al.* reported approximately 250-300 hatchlings released from one male.

Teixiera and Musick (2001) reported that the number of eggs/embryos found in the male brood pouch of lined seahorse, *H. erectus* varied from 97 to 1552 (80-126mm TL) whereas the number of hydrated oocytes in female varied from 90 to 1313 (60-123mm TL). Both the number of eggs/embryos and hydrated oocytes were better linearly correlated to total weight than total length.

Vincent and Giles (2003) observed that female size was the key determinant of the number of young released by the male, based on an analysis of 27 broods born *insitu* to wild male *H. whitei* with known partners. There was also an apparent decline in both the number of young per brood, and the size of those young over the breeding season. Vincent and Giles (2003) suggested that the size of the brood and that of the young might be more proximate indicators of reproductive success in seahorses rather than in other fishes, because they could be measured at the time of release (here 20-22 days after fertilization), after which survival was presumed to be relatively higher than in other species. The best model, however, explained <40% of the brood size.

5.5. Courtship and breeding behaviour

The results on the observation of the copulatory behaviour of male and female *H. kuda* in the present study indicated that seahorse have a peculiar breeding and courtship behaviour in which they form monogamous breeding pairs, which is reinforced by daily greetings in the breeding tank. Males were found to compete more intensely for access to mates than did females. The males brightened up during courtship were actively seeking for females that were brightened and ready to respond. These results were in conformity with those of Vincent (1994b, 1994c and

1995a) who investigated the courtship behaviour of *H. fuscus* in the laboratory, and those of Vincent and Sadler (1995) on the field studies on *H. whitei* that revealed both these species to be monogamous, with a single male and female mating repeatedly and exclusively over the course of the reproductive season. Masonjones and Lewis (1996) also observed that the dwarf seahorse *H. zosterae* formed monogamous pairs that court early each morning until copulation took place.

Seahorses possess the greatest specialization for paternal care, with females depositing their eggs directly into an abdominal brood pouch on the male where fertilization takes place (Fielder, 1954). In *Hippocampus* the male brood pouch is highly vascularised and provide gas exchange and osmoregulation for developing embryos throughout gestation (Boisseau, 1967a; Linton and Soloff, 1964). Due to their high degree of morphological specialization for paternal care, seahorses are an important group for testing the prediction that relative parental investment determines sex roles during courtship. Sexual selection theory predicts that the relative investment made by males and females in their offspring is a primary determinant of sexual selection, intensity and patterns of courtship behaviour within species (Trivers, 1972; Williams, 1975; Thornhill and Gwynne, 1986). Across the animal kingdom, female investment in offspring typically exceeds that of males, and traditional sex roles during courtship involve males playing a more active role in initiating courtship, males competing for access to females and females being selective about males (Trivers, 1972; Williams, 1975, Gwynne, 1991). Males, however, provide considerable parental care in many groups (Ridley, 1978), which may take the form of egg incubation or aeration, protection, or provisioning of juveniles.

In species where male investment exceeds that of females, like that in seahorses, sexual selection theory predicts that these traditional courtship patterns should be reversed. However, studies on *H. fuscus* (Vincent *et al.,* 1992; Vincent, 1994b, Vincent and Sadler, 1995; Masonjones and Lewis, 1996), which were confirmed in *H. kuda* by the present study, have shown that males compete more intensely for access to mates than do females, indicating that extreme male care is not associated with courtship role reversal, as has previously been assumed (Trivers, 1985).

The present study provided a detailed description of the courtship behaviour in *H kuda* that revealed several major behavioural changes occurring among the four distinct phases of seahorse courtship. Brightening and reciprocal quivering characterized the first phase of courtship that occurred in early morning for two days prior to copulation. On the day of mating there were three distinct phases of courtship, marked by the appearance of female pointing and males pumping. In the next phase, the male exhibited an increasing tendency to pumping, rather than to pointing and quivering in response to female pointing. The response of the male at this phase in the present study was slightly dissimilar to the courtship behaviour described by Masonjones & Lewis (1996) who observed that the male responded to female pointing, more by pointing than by quivering and pumping. In the final phase of courtship, the pairs repeatedly rose together in the water column, ending in midwater copulation during which the eggs were deposited by females directly into the male brood pouch.

The initial courtship behaviour during the first phase in *H kuda* in the present study is similar to the elaborate sunrise greeting rituals that have been described for field populations of the pipefish *Corythoichthys intestinalis* (Gronell, 1984) and *H. whitei* (Vincent and Sadler, 1995), both of which exhibited monogamous pair-bonding throughout a reproductive season. It has been suggested that daily repetition of this elaborated courtship display serves to facilitate reproductive synchronization of males and females (Gronell, 1984; Vincent, 1995a). Laboratory experiments on *H. fuscus* indicated that this daily greeting plays a role in the establishment and maintenance of pair bonds (Vincent, 1995a), since females were found to mate preferentially with their greeting partner, rather than with their previous mate.

Masonjones and Lewis (1996) had described a latency period lasting 23-220 minutes in courting *H. zosterae*, after the phase 2 of courtship, during which no courtship behaviour was observed and the females were not bright. This was observed in the present study, except that the female was also bright, but not responding to the males, which continued to show pumping behaviour. This latency period on the day of mating might coincide with the final stage of oocyte maturation during which eggs are hydrated prior to ovulation (Wallace and Selman, 1981; Selman *et al.,* 1991).

Ovulation seems to represent an irreversible commitment by the female to transferring eggs, since, if pairs are separated after this point, the female would eventually release the unfertilised clutch into the water (Masonjones & Lewis, 1996). This was noticed in the present study among the unsuccessful pairs where one female was found to carry a string of reddish eggs attached to its tail (Plate 10 B). The increasingly active role played by the female in initiating pointing and rising in the two final courtship phases following ovulation might reflect the exigency for a female to find a male to fertilize and incubate her eggs. In addition to the large material investment in eggs, loss of clutch is also costly because these females generally do not mate again until after the normal gestation period would have elapsed (Vincent, 1994c).

Evidence of monogamy was found in the aquarium studies of seahorse, *H. kuda* in the present study. The male and female of each pair of *H. kuda* stayed close together and moved as a pair for the entire period, mating repeatedly, and confining their reproduction to the same partner. These findings fit the definitions of monogamy applied to fishes by Barlow (1984, 1987, 1988) and Wickler and Seibt (1981). Spawning occurred only within pairs, even when up to five pairs were maintained in the aquarium. The close pair bonding and the fact that mature females did not respond to courtship by males other than their own mate suggest that some kind of individual recognition and mate fidelity exists in *H. kuda*, as has been suggested in the case of the seamoth *Eurypegasus draconis* (Herold and Clark, 1993). The presence of some mechanism (pheromonal or visual) for such recognition was found in the pipefish *Corythoichthys intestinalis* (Gronell, 1984).

Monogamy has been defined as a mating system in which an individual reproduces sexually with only one partner of the opposite sex (Wickler and Seibt, 1981) or a male and female that confine most of their spawnings to the same partner, not necessarily for life (Barlow, 1984, 1988). Evidence of monogamy has been reported for thirteen families of reef fishes (Barlow, 1984), among which are two families closely related to Syngnathidae, namely pegasids and the pipefishes (Pictsch, 1978). In the Syngnathids, the male incubates the embryos on his ventral surface, usually in a brood pouch. Some species pair only during mating time (Gronell, 1984; Vincent, 1990), while others remain paired for non-mating activities as well (Barlow, 1984). Gronell (1984) and Vincent (1990) who worked on the pipefish

Corythoichthys intestinalis, and Vincent (1990) who worked on *Hippocampus* spp. where a male and female spend most of the time separated, concluded that monogamy evolved to maximize reproduction efficiency. In the Solenostomidae, the female retains the fertilized eggs in a pouch formed by her pelvic fins. After hatching, the young in Syngnathidae and Solenostomidae are released into the water as miniature adults. In contrast, the species of the Pegasidae are broadcast spawners, but like solenostomidae are rare and usually found in pairs (Herold and Clark, 1993).

Jones *et al.* (1998) studied the four polymorphic microsatellite loci to assess the biological parentage of 453 offsprings of 15 pregnant males from a natural population of the Western Australian seahorse *Hippocampus angustus*. Microsatellite genotypes in the progeny arrays were consistent with a monogamous mating system in which both females and males had a single mate during a male brooding period. Multilocus genotypes implicated four females in the adult population sample as contributors of eggs to the broods of collected males, but there was no evidence for multiple mating by females. Based on genotypic data from the progeny arrays, two loci were linked tightly and the recombination rate appeared to be approximately 10-fold higher in females than in males.

Anisogamy among vertebrates results in asymmetry in the interests of males and females. Where no parental care is involved, males are expected to be monogamous only if they cannot acquire and support additional females (Thresher, 1984; Barlow, 1988; Donaldson, 1989). The reproduction success of males is limited by the number of eggs they fertilize (Baylis, 1981). Males therefore are expected to compete for females, seek to monopolise them when possible, and minimise the time between inseminations (Williams, 1966; Trivers, 1972). The pattern of animal dispersal and their mating systems may be affected by the pattern of distribution of resources in space and time (Orians, 1969l Emlen and Oring, 1977, Wickler and Seibt, 1983; Barlow, 1988). Widely dispersed food might result in dispersed and solitary females. Under these conditions, non-territorial males might maximise their reproductive efficiency by searching out a female, remaining with her and defending exclusive access to her resulting in monogamy (Wittenberger and Tilson, 1980; Barlow, 1988). Similar characteristics of monogamy apply to *Malacanthus latovittatus,* a Red sea tile fish, with females so widespread that a male can 'sequester' only one female at a time and new mates are not readily available (Clarke and Pohle, 1992). Masonjones (2001) determined the effects of monogamous pair bonding, and subsequent reproduction on the metabolic rates of dwarf seahorses, *Hippocampus zosterae*. She observed that specific metabolic rates only differed by gender during male pregnancy, when male metabolic rate increased from 10 to 52% over pre-gravid levels. A male's developing brood only explained 4-31% of this increase, suggesting that increased metabolic demands on fathers accounts for most of the increase in metabolic rate during gestation, suggesting that pair bonding can strongly affect the general metabolism of organisms, with potential differences between males and females that increase with age.

Factors of low density, low mobility and increased reproductive efficiency are most likely to account for monogamy in *H. kuda*. With no need for mate searching and reassessment, courtship time is shorter and predation risk is reduced.

5.6. Juvenile rearing

H. kuda appears to display relatively rapid growth, and the results obtained in the present study are comparable to some of the other seahorse species that have been cultured in captivity. Woods (2000a) reported a growth of 43mm in standard length at 56 days of age in the case of *H. abdominalis,* and later reached 110.7mm after a year (Woods, 2000b). Job *et al.* (2002) obtained growth rates for *H. kuda* as high as 85.8 mm in 56 days of rearing, and then 120.7mm in 98 days. They also obtained very high survival rates of up to 97% post hatch after 42 days. The results of the survival, and growth in length and weight of *H. kuda* (56%, 49.4 mm and 316mg) obtained in the present study after 60 days of rearing without light manipulation was more similar to that obtained for Woods (2000a) for *H. abdominalis*. The survival of (97%) obtained for *H. kuda* by Job *et al.* (2002) was unusually high. However, in the present study a survival of 91 % and growth of 36.2 mm and 66.14 mg were obtained after 14 days of rearing when the tanks were partially covered. The growth rate reported for some other species of seahorses also remained low. The Atlantic seahorse *H. erectus* reached a total length of 33.29mm at 35 days of age (Correa *et al.,* 1989).

5.6.1. Live feeds

5.6.1.1. *Artemia* nauplii

Good quality *Artemia* enriched by algae have been used to rear some species of seahorse with great success, achieving survival rates of 86% after 4 weeks for *H. abdominalis* (Woods, 2000a). Also Correa *et al.* (1996) recorded high survival in *H. erectus* fed enriched *Artemia* nauplii. The juveniles reared in the present study on three feed combinations revealed that the combination of enriched brine shrimp nauplii with mixed marine copepods gave the best results. The survival of the juveniles under the three combinations was, however, not significantly different among one another during the first two weeks of rearing. This might be due to that the hatchlings in all the three treatments were fed with freshly hatched *Artemia* nauplii alone during the first week of rearing, because of the small mouth size of the hatchlings, and the fact that the copepods were of mixed species cultured without any specific algal enrichment. The feed combinations involving copepods, enriched *Artemia* nauplii and Cyclop-eeze were introduced only on the 8th day.

It is well established that larvae and juveniles of most marine fish species require live prey with a high nutritional content. The feeding of seahorses are especially peculiar in that they prefer live moving feed alone, and they have a unique aversion to nonliving foods (Vincent, 1996) although they have recently been reported to have weaned to artificial diets (Vincent, 1995d, Giwojna, 1996a; Giwojna, 1995b; Baldassano, 1996). Freshly hatched nauplii of the brine shrimp *Artemia* have been widely used as a live feed in the larval rearing of marine and freshwater fish and prawns. Lavens *et al.* (2000) highlighted the role of *Artemia* as an essential larval diet in fish and prawn hatcheries. However, the quality of *Artemia* nauplii is affected by various factors such as the strains, locality and the season of harvest (Hsu *et al.*, 1970). The nutritional value of *Artemia* is marked by the absence of omega-3 polyunsaturated fatty acids (PUFAs), which are essential to the diet of marine fishes and crustaceans. Since the brine shrimp nauplii lack important nutritional requirements of the prawn larvae, such as essential fatty acids, enrichment using PUFAs was resorted to in the present study.

The content of PUFAs in the live feed is of particular importance during the first feeding stages of the larvae and juveniles of most marine fish species. Fish diets that contain docosahexaenoic (DHA; 22: 6n-3) and eicosapentaenoic acid (EPA; 20:5n-3) are highly desirable in the fish diet (Sargent *et al.,* 1997). The PUFA requirement of young seahorses is unknown, however, it might be similar to that of other marine fish larvae. Since Artemia nauplii contain very low levels of DHA, and the EPA being seldom present in detectable levels (Sorgeloose and Pandian, 1984), it is critical for marine larval predators as they need high levels of these fatty acids.

Sargent *et al.* (1997) reported that enriching *Artemia* nauplii with commercial preparations that are high in PUFAs make them more suitable for feeding young fish. Super Selco is a proven commercial product being used in many commercial fish and prawn hatcheries for enrichment of the *Artemia* nauplii before feeding to the larvae. Payne and Rippingale (2000) had also used Super Selco in the enrichment of *Artemia* nauplii during rearing of the seahorse juveniles. Reported DHA: EPA values for *Artemia* nauplii enriched with Super Selco varied from 0.3 (McEvoy *et al.*, 1998) to 0.8 (Kraul *et al.*, 1993).

The survival of the seahorse hatchlings reared in the present study on a feed combination of enriched *Artemia* and mixed marine copepods were significantly greater than that when enriched *Artemia* was given alone, or when enriched *Artemia* was supplemented with an inert feed such as freeze-dried Cyclop-eeze. Copepods were found to be a more efficacious diet than even enriched *Artemia* for rearing *H. subelongatus* juveniles (Payne and Rippingale, 2000). This supports the general assertion that *Artemia* are not an appropriate mono-diet for juveniles of some seahorse species (Lunn and Hall, 1998). Payne and Rippingale (2000) suggested that the copepod nauplii were better assimilated than *Artemia,* and this apparent difference in prey digestibility probably accounted for much of the difference in growth and survival between the two diets.

5.6.1.2. Marine Copepods

Tipton and Bell (1988) observed that in the sea, the diet of adult dwarf seahorses *H. zosterae* consisted mainly of copepods. The gut content analysis of *H. kuda* in the present study also showed a major percentage of copepods (22.84%) in its gut. Liang (1992) emphasized that pelagic copepods are indispensable for rearing seahorse fry. Also juveniles of the closely related pipefish feed predominantly on copepods in the wild (Franzoi *et al.,* 1993; Teixeira and Musick, 1995) and recorded very high survival when provided with cultured copepods in captivity (Payne *et al.*, 1998). Also the marine planktonic copepods are reported to have high nutritional value. Raymont (1971; 1983) observed that the *Calanus* spp. contained 10 - 40 % protein, 12 - 47 % lipid, 3 % chitin and 3 % ash (calculated as dry weight). The high PUFA content of copepods make them suitable as a diet for young fish (Watanabe *et al.*, 1983).

Payne and Rippingale (2000) reported that the early growth and survival of seahorse *H. subelongatus* were significantly greater when fed with copepod nauplii. Copepod nauplii were well digested by juvenile seahorses whereas *Artemia* nauplii were not. The survival rates obtained by Payne and Rippingale (2000) were slightly higher than the mean survival rate of 56% obtained in the present study for the feed combination of enriched *Artemia* and copepods. However, they found that when enriched *Artemia* alone was used the survival rates were down to just above 20%, which was quite low when compared with the mean survival obtained in the present study, which was 43% when enriched *Artemia* nauplii alone was fed to the juveniles. It was similar to the third feed combination of enriched *Artemia* and Cyclop-eeze, which yielded a mean survival rate of 21%.

The copepods used in the present study contained heterogeneous species and were not enriched with any microalgae, as against the unispecies culture of calanoid copepod *Gladioferens imparipes* enriched with microalgae *Isochrysis galbana* to be fed to the seahorse fry by Payne and Rippingale (2000). The mixed culture of copepods in the present study contained a majority of calanoid copepods such as *Eucalanus* spp., *Euchartia* spp. *Centropages* spp., *Labidocera* spp., *Acartia* spp., *Rhinocalanus* etc.; cyclopoid copepods such as *Oithona* spp., *Copilia* spp., *Sapphirina* spp. etc. and harpacticoid copepods such as E*nterpina* spp. and *Macrosetella* spp. that naturally occurred in seawater and were allowed to bloom. There was no control on the microalgae developed in seawater that facilitated the proliferation of copepods. This might be the reason for a slightly lower survival of the juveniles in the present study than that obtained by Payne and Rippingale (2000).

5.6.2. Nonliving feeds

One of the main bottlenecks in establishing economically viable and biologically successful seahorse aquaculture is the provision of sufficient quantities of nutritionally sound livė food. In their natural habitat, seahorses are visual predators that target live prey such as copepods, amphipods, mysid shrimp, and caridean shrimp (Reid, 1954; Lovett, 1969; Tipton and Bell, 1988). In captivity, aquarists, researchers and commercial aquaculturists have relied heavily on cultured live foods such as brine shrimp *Artemia*, copepods, mysids and amphipods, as well as collecting wild foods such as various assemblages of zooplankton (Correa *et al.*, 1989; Forteath, 1995; Lockyear *et al.,* 1997; Wilson and Vincent, 1998; Hilomen-Garcia, 1999; Payne and Rippingale, 2000).

Culturing the large quantities of live food required by seahorses in commercial culture could prove difficult and costly. Costs of establishing and maintaining a healthy live food culture system might ruin the economic feasibility of a commercial venture of seahorse rearing, and therefore alternative diets to live feed need to be investigated and tested (Woods, 2000a). Mixed feeding of live and non-live diets is a commonly used strategy to help wean larval fish onto non-live or manufactured foods and has been shown to enhance larval growth and survival beyond that achieved by feeding either types of food alone (Drouin *et al.,* 1986; Ehrlich *et al.,* 1989; Abi-Ayed and Kestmont, 1994; Rosenlund *et al.,* 1997; Daniels and Hodson, 1999).

The presence of *Artemia* increased the dry microdiet assimilation by 30-50% in seabass (*Dicentrarchus labrax)* larvae. Seahorses have not generally been reared on artificial foods in commercial culture, due to difficulties in getting them to accept nonliving foods. However, there are general reports of commercial seahorse culturists using artificial foods to some degree, such as shrimp and fishmeal based diets (Chen, 1990; Forteath, 2000). Frozen foods such as frozen mysids and copepods are also utilised to feed seahorses (Garrick-Maidment, 1997; Forteath, 2000). The ability of seahorses to utilise nonliving foods in the rearing of *H. kuda* has important implications for the commercial culture of this species, as the use of non-live foods can dramatically reduce material and labour costs, that in turn potentially increases the economic viability of a commercial operation. Nonliving foods also provide for a more predictable and reliable food source.

Results of a survey of aquarists and researchers who kept seahorses gave no clear consensus on preferred juvenile diets (Lunn and Hall, 1998). For the difficult-to-rear species of seahorses, live feeds other than *Artemia* must be found. The freeze-dried Cyclop-eeze used in the present study is a very popular larval feed in crustacean hatcheries, and ornamental fish rearing. It is a copepod cultured in a pristine Arctic lake and preserved in frozen or freeze-dried form and is nutritionally superior to *Artemia*. Marco (2003) reported the use of Cyclop-eeze in the diet of adult *H. zosterae*, and feeding at various stages in the development of juvenile *H. abdominalis*, *H. kuda*, *H. erectus*, *H. breviceps*, the Dusky pipefish *Syngnathus floridae*, and the Northern pipefish *Syngnathus fuscus*. In the present study, one-week-old juveniles of *H. kuda* could be successfully weaned onto the freeze-dried Cyclop-eeze, though the results were not better compared to that of the live feeds tested. The lower survival of hatchlings fed *Artemia* and Cyclop-eeze might be due to the comparatively lower acceptability of the hatchling towards it being an inert feed.

The survival and growth of the juveniles of *H. kuda* reared on freeze-dried Cyclop-eeze in the present study was the lowest compared to that when fed on *Artemia* or copepods. Inadequacies in the nutritional profile of the frozen artificial diet (for example, inadequate levels of certain lipids, proteins or carbohydrates) in relation to the dietary requirements of *H. kuda* could be one of the reasons for this lower survival and growth of juveniles fed this diet. There has however, been no reports of the optimal nutritional profile for *H. kuda*. Although the juveniles were physically capable of ingesting the size range of Cyclop-eeze offered, there remained a good proportion of this feed in the tank that were not consumed. This was in contrast to the juveniles offered *Artemia* nauplii, where there was virtually no wastage. *Artemia* nauplii were relentlessly hunted down and consumed. In the present study, when Cyclop-eeze was presented to the juveniles, they first carefully scrutinised the feed before striking. On introduction of food into their tanks the juveniles would become alert and both eyes would be directed at the food. The juveniles would then move their bodies to keep the food at the optimal striking distance from their snouts while they scrutinised it. Juveniles would often inspect and then reject many individual Cyclop-eeze copepods before actually striking and ingesting one.

The orientation of the head of the juveniles towards individual Cyclop-eeze copepods, turning of both eyes towards the nonliving food, but not striking and then turning away would seem to indicate that nonliving foods could not incite the necessary feeding trigger in the juveniles of *H. kuda*. This might also be as a result of the physical damage to the Cyclop-eeze copepods during freezing, which rendered them unattractive or unrecognisable as prey. Examination of the Cyclop-eeze copepods under microscope revealed that it contained many individuals in a fragmented state, although almost 50% were intact (retaining the complete copepod shape). This freezing damage might account for the rejection of many Cyclop-eeze copepods. The freeze damage could still be more in the case of frozen Cyclop-eeze, as the freeze-drying process imposes minimum damage to the constitution of the copepod organism.

In the present study, the juveniles offered *Artemia* nauplii started feeding them immediately, rapidly filling their gut, and continued to feed on as long as the nauplii were available. This constant feeding might have resulted in low retention time of food in the gut and poor food assimilation. In contrast, copepods were well digested. This was confirmed by the examination of the faeces of the seahorse juveniles which was found to contain intact *Artemia* and Cyclop-eeze, whereas there was not that many whole copepod, which might be due to the poorer digestion of *Artemia* and Cyclop-eeze, compared to the copepods. This apparent difference in prey digestibility also probably accounted for much of the difference in growth and survival between the three diets.

Given the relative difference in the digestion of *Artemia* and Cyclop-eeze, copepods could be a clearly more efficient diet compared to the former two. Given the almost ubiquitous presence of copepods in the sea it is likely that seahorses have evolved to recognize them as prey and to benefit nutritionally from them. In contrast, *Artemia* occur naturally in saline lakes, that they have not been available as food during the evolution of seahorses (Payne and Rippingale, 2000). While this does not necessarily make them an unsatisfactory food, given the fact that *Artemia* has now emerged to be the universal live feed in aquaculture, it might explain why they are less beneficial than copepods. Moreover, there is presently no such a convenient and effective alternative diet to *Artemia* for feeding during the initial stages, the mouth size of the hatchlings being very small. Good quality *Artemia* enriched by algae have also been used to rear some species of seahorses with great success, achieving survival rates of 86% after 4 weeks for *H. abdominalis* (Woods, 2000), and above 80% in *H. erectus* (Correa *et al.*, 1996).

There has also been some reports that highlighted the efficacy of a gradual reduction of the live food component during mixed feeding that was effective in increasing larval fish growth and survival. Rosenlund *et al.* (1997) found that halibut (*Hippoglossus hippoglossus)* larvae, fed decreasing amounts of *Artemia* along with a dry diet, experienced higher specific growth rates than larvae fed solely with *Artemia.* Daniels and Hodson (1999) found that in the flounder *Paralichthys lethostigma,* while weaning the post-metamorphosis larvae off *Artemia* onto dry and semimoist artificial feeds, the optimum growth and survival occurred at 20 days with abrupt cessation of the live feed. However, this weaning period could be shortened when gradual weaning was employed. It would therefore be worthwhile in future to compare the success of mixed feeding of *Artemia* and artificial feed by using both abrupt stopping and gradual reduction of the live feed, in seahorses.

5.6.3. Stocking density

In a commercial point of view, the highest survival alone is not the only criterion that determines the success of a hatchery operation; the production per litre has a more meaningful significance than the percentage survival. In the present study, the production of seahorse juveniles obtained per litre was also considered in view of its commercial application. Although the stocking density at which the best growth and survival was obtained as 2 L^{-1}, the one which yielded the highest production per litre was 3 L^{-1}. However, the survival and growth, particularly in weight, was significantly reduced at stocking densities of 4 and 5 L^{-1}. Hence the stocking density of 3 L^{-1} was assumed to be the optimum density that is commercially viable, although the survival rates were higher at lower densities of 1 and 2 L^{-1}. This is in line with the proven fact that in commercial finfish aquaculture, if satisfactory growth, survival and fish health are not compromised, then the higher the stocking density, the lower the potential production cost per fish may be (Baskerville-Bridges and Kling, 2000).

An inverse relationship was observed between stocking density of the hatchlings and the growth in length and weight, which were reduced at higher densities of stocking. Survival was also significantly lower in the treatment of 5 and 6 juveniles L^{-1}. In finfish aquaculture, stocking density can not only affect fish growth, but it has also been shown to alter behavioural interactions (Wallace *et al.*, 1998; Haylor, 1991, Suresh and Lin, 1992; Hossain *et al.*, 1998; Wang *et al.*, 2000). However, the effect of stocking density on the growth and behaviour of fish is largely species specific, and therefore determining such effects in different fish species is vitally important in commercial culture.

The lower growth and higher mortality in the higher stocking density treatments in the present study might be the result of some biological/social factors connected with space at high densities of stocking, rather than poor water quality and competition for food. The water quality in densely packed cultures of animals is likely to get worse, because of increased accumulation of metabolic wastes and uneaten feed (Irwin *et al.*, 1999). However, in the present study daily exchange of 50% of the culture water was done, so that the water quality remained stable, as evidenced by the regular monitoring of water quality parameters, which were near optimum.

In addition to feed competition, in the case of seahorses, behavioural changes also seem to have contributed to poor growth in higher stocking densities in the present study. The juveniles stocked at higher densities especially 5 and 6 L^{-1} showed increasing tendency for 'tail wrestling' with each other, wherein one juvenile strongly held the other with the tail around its trunk or tail, impeding each other's movement and even feeding. This grasping and wrestling with each other might have contributed to low feed intake and expenditure of excess energy, with consequent impacts on growth and survival. Tail wrestling was particularly pronounced during feeding when juveniles would arise from their holdfast into the water column for feeding, and then would often grasp any other juveniles nearby if a contact were made, while attempting to feed. Grasping and wrestling were more frequently observed during feeding in the 5 L^{-1} treatment, than the 3 or 4 L^{-1} treatment in the present study.

More works need to be done as to reduce such behavioural problems at higher stocking densities by the use of different types of artificial substrates as hold fasts for anchorage of the juveniles. This might reduce the interaction among juveniles in the rearing tank, leading to better feed consumption, growth and survival.

5.6.4. Salinity and light

The juveniles of *H. kuda* reared in the present study were found to grow equally well from salinities ranging from 15 to 35 ‰. This is promising since it opens up the possibility of culturing seahorses in brackish water as well. The only earlier report of the successful rearing of *H. kuda* under different salinities was by Chaladkid and Hruangoon (1996) in Thailand, who obtained the highest survival rate of 60.67% while rearing the juveniles at 15 ‰ compared to 20, 25, 30 and 35 ‰. The survival rate obtained in the present study was slightly less (53.86 %) at 15 ‰, but the growth in length and weight were encouraging. Chaladkid and Hruangoon (1996), however, obtained the lowest survival rates of juveniles at 30 ‰ (31.34 %), which is contrary to the findings in the present study in which 30 ‰ was found to be the optimum salinity for the rearing of *H. kuda,* registering the highest mean survival of 60.56 %. Chaladkid and Hruangoon (1996) obtained better survival rates of 52.67 %, 34 % and 36.67 % at 20, 25 and 35 ‰ respectively. The corresponding survival rates obtained in the present study were 55 %, 58.34 % and 59.23 %. However, there was no statistically significant difference in terms of the percentage survival and the mean weight gained by the juveniles among the salinities of 15, 20, 25, 30 and 35 ‰, suggesting that *H. kuda* could be grown successfully in the salinity range from 15 to 35 ‰. Hatchling was also found to occur in a range of salinity 5 to 50‰.

In the present study a survival of 91 % and growth of 36.2 mm and 66.14 mg were obtained after 14 days of rearing when the tanks were partially covered. The increment in weight achieved by the juveniles were much higher than that achieved while rearing without light manipulation, although, the length attained by the juveniles were less.

Visibility of the prey is important in the efficient feeding in larval rearing since It is established that vision is the primary sense used in prey detection and capture in many teleost fish (Blaxter, 1980). Therefore, characteristics of the prey (like shape, colour, movement etc.) when viewed against different backgrounds by fish can affect their feeding efficiency, and consequently their growth and survival (Naas *et al.*, 1996; Martin Robichaud and Peterson, 1998; Planas and Cunha, 1999). This suggests that small *Artemia* nauplii are visually differentiated from their background more effectively by the seahorse juveniles in clear containers. However, Naas *et al.* (1996) considered black tanks to be the best choice for larval fish rearing as compared with a white environment, since it would serve to avoid 'wall trapping' due to various phototactic responses of the larvae.

Light intensity can modify the effect that tank colour has on feeding behaviour (Martin Robichaud and Peterson, 1998), as well as influencing overall feeding efficiency and consequently growth and survival (Batty, 1987; Huse, 1994; Downing and Litvak, 1999). Woods (2000a) reported that the juveniles of *H. abdominalis* were still positively phototactic at 1 month of age, but might be less confused by white tanks at that age. This was definitely the case for older (73 months) *H. abdominalis*, which appeared largely unaffected by white tanks, as they did not orient to the walls near the surface of white tanks as new born juveniles did; instead they dispersed throughout the tank and could accurately feed on moving prey.

Since *Artemia* are positively phototactic, top-illumination will result in *Artemia* congregating near the water surface in tanks, where this is the major source of illumination. When feeding on this *Artemia*, the juvenile seahorses that have access to the water surface are prone to ingest air bubbles. If the ingested air bubbles are not expelled from the gut they can cause buoyancy problems and restrict feeding. In the present study, higher survival was obtained for the juveniles that were prevented from accessing to water surface while feeding by blacking off the top of the tanks. When the sides of the tank were illuminated by the diffused sunlight, the *Artemia* nauplii congregated near the sides at least 10 cm below the water surface so that the juveniles also assembled among the nauplii and started active feeding. This resulted in a greater feeding efficiency and less risk of buoyancy problems due to ingestion of air bubbles.

In the present study, hatchlings immediately after release from the brood pouch of the male were seen to rise to the water surface and gulp in air for a while. This is probably important for the hatchlings of seahorses, as they appear to initially inflate their swim bladder through the ingestion of air at the water surface. Non-inflation of the swim bladder in fish may result in dysfunctional buoyancy and atrophy of the swim bladder (Battaglene and Talbot, 1990; Martin Robichaud and Peterson, 1998). Lawrence (1998) attributed the main cause of mortality in juvenile seahorses, *H. angustus* to poor swim bladder inflation as a result of an oily surface film that prevented juveniles from initially inflating their swim bladders.

Hyperinflation of the swim bladder has also been reported which has been attributed to gas super saturation (Cornacchia and Colt, 1984), or stress caused by such factors as inadequate water depth (Kolbeinshavin and Wallace, 1985), and excessive air ingestion (Nash *et al.*, 1977), and may hinder normal swimming, or in extreme cases, result in floating fish and increased mortality (Weitkamp and Katz, 1980). During many of the experiments in the present study floatation of the hatchlings was one of the major reasons for their mortality. This was considerably reduced by using the partially covered tank for rearing.

5.6.5. Tolerance

There has been no published reports of tolerance studies of the juveniles of *H. kuda* to any of the water quality parameters such as salinity, pH etc. In the present study the juveniles of H. *kuda* were found to be reasonably tolerant to extreme salinity and pH. The juveniles transferred to freshwater survived up to 10 hours. The natural habitat of seahorse in the wild include corals, seagrasses or mangrove ecosystems. Most seahorse are fully marine, although some species such as *H. capensis* live in estuaries where they might experience fluctuating salinity and suffer mortality during freshwater flooding (Whitfield, 1995). There has not been a reliable evidence of freshwater seahorses till date, although Roule (1916) described seahorses from the Mekong River, 300 km upstream of some waterfalls. This account was however, third hand and highly unlikely to be correct, especially given the other inaccuracies in the paper.

Lourie *et al.* (1999a) had observed that seahorses could act as flagship species for their endangered habitats in the world such as corals, mangroves and seagrass ecosystems. They face a range of threats including pollution, destructive fishing methods, encroaching urban and industrial development, siltation, extraction and so on (Hatcher *et al.*, 1989). These factors influence significantly to limit seahorse distribution in the wild.

The tolerance of seahorses to these limiting factors also affects their endurance in captivity. Farming of seahorse have proven technically challenging because of problems with diet and diseases. Scrupulous hygiene is required to prevent these fishes from a wide range of parasitic, fungal and bacterial ailments (Lourie *et al.*, 1999a). Formalin is one of the most commonly used and widely accepted chemotherapeutic agents in the treatment of common diseases in finfish and shellfish. The LC_{50} values obtained for formalin in the present study indicate that *H. kuda* could tolerate moderately high levels of formalin. For therapeutic purposes a dose of 250 ppm could be tried as the initial dose, and further studies are warranted to determine the therapeutic levels of formalin that can be used for treating specific pathogens or parasites in seahorses.

The fairly rapid growth and high survival of *H. kuda* obtained in the present study suggests feasibility of development of culturing of this and other species in India. *H. kuda* is a highly valued species in the traditional Chinese medicine as well as the live aquarium trade (Lourie *et al.*, 1999a). The high prices commanded by seahorses in trade make it likely that seahorse aquaculture could prove commercially viable. The provision of live feed in good quantities and application of appropriate feeding strategies would be the major determinants in the success of seahorse culture. Standardisation of a rearing protocol that takes into account the unique feeding patterns and other related husbandry issues peculiar to seahorses alone will be useful. Given that the seahorse populations remain the mainstay in the livelihood of many fisher folks in different parts of the world, aquaculture efforts targeted at seahorse fishers in source countries, especially India could provide a sustainable alternative. This would attain the twin goals of satisfying the increasing market demand for seahorses, while achieving both conservation and development objectives.

5.7. Conservation of seahorses

Seahorses are vulnerable to degradation of their preferred sea grass, mangrove, and coral reef habitats in addition to their depletion due to fishing. The greatest pressure on seahorse populations appears to come from the accelerating consumer demand in China, as a result of rapid economic growth. Exploitation is global, and Europe and North America utilize vast numbers of seahorses as aquarium fishes and curios. TCM might be the biggest user of seahorse, but taking seahorses as pets or curios had as severe an impact on the wild population as taking them as medicine. Further, in those regions where TCM has not yet begun, to accept small seahorses it is the aquarium trade that extract juveniles, while the curio trade (primarily for the Western market) consumed many seahorses for souvenirs and ornaments (Vincent, 1996). The reason to be panic is that some species of seahorses have already been included in the IUCN red list of threatened species (Vincent, 1996).

There are several reasons why the seahorses should be preserved; the major ones being ecological, biological, and economical as well as medicinal. Syngnathids are the dominant family of fishes across a wide range of seagrass habitats in diverse geographic areas around the world (Pollard, 1984) and are important predators on benthic organisms (Tipton and Bell, 1988). This means that removing them could well disrupt the sea grass ecosystems. Disturbing community integrity will present risks to other species and thus promote the loss of biodiversity (Vincent, 1996).

Biologically, the extraordinary life history of seahorses; the male becoming pregnant and pairs faithfully monogamous, offers an unusual opportunity to explore our understanding of the evolution of sex differences. For instance, seahorses allow biologists to test theories about how parental care limits reproductive rate in one sex and thus promote greater mating competition in other sex (Clutton Brock and Vincent, 1991). Such competition for mates is thought to explain why one sex (usually males) becomes larger, brighter, or more ornamental. Moreover, sexual fidelity to one partner is proving sufficiently rare among animal species to make the condition favouring seahorse monogamy particularly worthy of study (Vincent and Sadler, 1995).

Subsistence fishers in many exploiting nations obtain a substantial portion of their annual income from seahorses. Such dependence is likely to increase as other fisheries resources continue to decline. Exploitation may continue up to the point when seahorses disappear, no matter how poor the catch becomes, because artisanal fishes often catch seahorses in conjunction with obtaining food for their families. Since the medicinal use of seahorses has still not been scientifically substantiated, they should be evaluated for biomedical substances that are potentially useful in the treatment of various ailments.

Thus the conservation concerns of seahorses are many, and any attempt of conservation of seahorses should take into consideration the unique features of its fishery. Seahorse trade volumes are large, amounting to many millions of seahorses annually. There is a global involvement, with at least 32 nations trading seahorses of at least 45 MT among them (Vincent, 1996). Seahorses often sell as a valuable commodity, selling at up to US$ 1200 per kilogram in Hong Kong during 1995 (Vincent, 1996). They are economically important to many artisanal fishers and medically important to many Chinese consumers. The demand for seahorses invariably exceeded supply, and it is likely that this demand will continue to grow, particularly as a consequence of China's economic boom. The most alarming fall out of this trade would be that the seahorse numbers are declining rapidly, and many harvests becoming smaller, when juveniles were also being actively exploited (Vincent, 1996). The number of seahorses in fished population is declining rapidly even as the demand for seahorses expands.

Seahorses are caught by artisanal or subsistence fishers, or as a by-catch of trawling, although target fishery is in existence in several areas, including India. Large scale mechanised fisheries for seahorses are unknown, and are unlikely ever to be viable, because these fishes are patchily distributed, recolonise slowly, and are often found in areas that are difficult to access with fishing gear such as coral reefs or mangroves. However, incidental by-catch from shrimp trawling and other forms of net fishing is an important contributor to the seahorse trade in many areas including India. The intensity of effort dedicated to collecting seahorses depends on their availability relative to other fisheries resources, as well as on other income earning opportunities.

In the Philippines, seahorses comprise of up to 80% of fishers annual incomes, and up to 100% of the money earned during peak seahorse catch months (Vincent, 1996). In India, Marichamy *et al.* (1983) reported that concomitant with the decline in catch of sea cucumbers, a boom in seahorse fishery emerged in the south Tamil Nadu coast. Most fishers earned half of their annual income, or some even cent percent from seahorses. Given the economic dependence of a large section of the fishermen population on seahorses, any effort on regulating their exploitation should be done with caution. The blanket ban on the fishery and trade in India is no way near to any solution to the plight of seahorses since a full-fledged study is yet to be attempted to delineate the population dynamics of seahorses in Indian waters.

The present study showed that the seahorses in the south Tamil Nadu coast are subjected to relatively heavy fishing pressure. But the numbers have not come down alarmingly. Marichamy *et al.* (1993) and Vincent (1996) had reported that the annual catch of seahorses would be about 3.6 - 4.8 MT in 1992 and 3.6 MT (1.5 million numbers) respectively. In the present study the annual landings of seahorses from Southern coast was obtained as 9.75 MT (2.65 million individuals), which means that there has been a substantial increase in the seahorse landings in this coast. This might also be due to the increased effort (855 boats per month in the present study) in recent years. Therefore, the conservation efforts should be more realistic in that the stakeholders in trade as well as fishery resources do not suffer. An exhaustive study on the population and fishery characteristics so as to determine a sustainable yield level should first be undertaken. Any further efforts on conservation shall be based on this study.

Conservation and trade should go in consonance and one should not be at the expense of the other. The ban on collection of seahorses and sea cucumbers in India has put thousands of fishermen who subsisted on these resources for their livelihood into great hardship. Sreepada *et al.* (2002) highlighted the plight of Indian seahorses due to their exploitation along the Indian coast, and the conservation and management of seahorses are currently limited by the absence of data on the abundance and distribution of seahorse species in the region. Thus any serious attempt of conservation should include the other popular strategies of fisheries management, such as closed seasons, and or delineating marine sanctuaries which would serve as flourishing grounds for seahorses. Regulating or prohibiting fishery of seahorses during the peak breeding season (at least during the month of August in Thondi) could be considered as one such option. This might have a beneficial effect on sustainability of the stock. Regulation of effort (the number of boats operating on peak season of availability and breeding season) could also be resorted to.

Seahorses depend on their habitats to survive. Thus attempts to diminish the impact of the trade on seahorse populations might be ineffectual unless protection and management are also sought for their vital sea grass, mangrove and coral reef habitats. These are highly productive ecosystems, that are being degraded and lost through dredging, dumping and polluting, sitting, clearing, felling, dynamiting and cyanide fishing (Hatcher *et al.*, 1989). Pro-active measures should be implemented to ensure the rejuvenation of these areas so as to make them suitable for seahorses and other marine fauna.

Vincent and Pajaro (1997) reported a novel community based management programme for sustainable seahorse fishery in the Philippines. As part of the world's first seahorse conservation and management project at Handumon village in the Central Philippines, a three-pronged strategy was developed, based on a socio-economic study, which included protective measures, fishery modification and enhancement efforts. A 33 ha, no-exploitation sanctuary and an adjacent traditional fishery zone was established, and enforced at Barangay. The pregnant males caught were being placed in sea cages from where the newborn young could escape before the male was sold. The fishers also re-seeded areas depleted of seahorses and had begun developing seahorse culturing skills.

These are some of the strategies that could be considered in the Indian context. Serious aquaculture efforts should also be undertaken so that seahorses of different species could be reared under captivity and used for sea ranching in their preferred habitats. The present study and several other studies in different parts of the world have shown that seahorses could be successfully reared under captivity. Therefore, it is imperative that the regulation of seahorse fishery aimed at its conservation has to be realistic, and any such effort disregarding the subsistence fisherfolk would be futile, and far from its objective.

SUMMARY

SUMMARY

- Seahorses generally occur in areas where there is abundance of sea grasses, sponges and corals. In India an organised fishery and trade for seahorses exist only in the southern coast of Tamil Nadu, along the Palk Bay and Gulf of Mannar.

- A target fishery for seahorses existed in Palk Bay where seahorses used to be collected by divers, along with sea cucumbers and chanks. In the Gulf of Mannar region, which provides a less suitable habitat for seahorses, most of the landings were as by-catch of shrimp trawling. The major fishery occurred from May to October, with peak in the month of August, and the lean fishery during November to April.

- Palk Bay region contributed 76% (13.867 MT, wet weight or 20,12,616 numbers) of the total annual landings of seahorses from the South Tamil Nadu coast (18.246 MT or 26,48,179 numbers). The major centre of seahorse landings was Thondi that contributed 68% (9.43 MT or 13,68,579 numbers) of the seahorses landed in Palk Bay.

- The volume of seahorse trade from India was estimated as 9.75 MT of dried seahorses in 2001, which was much higher than the MPEDA estimate of 4.34 MT exported from India during 2001-02, underlying the fact that a lion's share of the exports might be through non-conventional means and had gone undeclared.

- Six species of seahorses namely *Hippocampus borboniensis* Dumeril 1870, *Hippocampus spinosissimus* Weber 1913, *Hippocampus kuda* Bleeker 1852, *Hippocampus fuscus* Ruppell 1838, *Hippocampus trimaculatus* Leach 1814 and *Hippocampus guttulatus* Cuvier 1829 were identified from the South Tamil Nadu coast. There were four morphotypes of seahorses, which could not be identified with any presently known species.

- At Thondi, *H. borboniensis* was found to be the major species (27.96%), followed by *H. spinosissimus* (22.14%), *H. kuda* (20.9%), *H. trimaculatus* (14%), *H. fuscus* (9%) and *H. guttulatus* (4%). Individuals of mean wet length and weight, 11.5 ± 2.36cm and 6.89 ± 2.041g respectively, contributed to the catch.

- The major size classes represented in the fishery were 145-175 mm, 145-165 mm, 105-190 mm, 110-165 mm, 140-190 mm and 150-190 mm respectively for the six species collected from Thondi in 2001. The growth and catch curves derived from the analysis of length frequency data by FiSAT II led to the growth and mortality parameter estimates as $L\alpha$ = 220.52 mm, K = 0.55 $year^{-1}$, Z = 1.27 $year^{-1}$, M = 0.72 $year^{-1}$, F=0.56 $year^{-1}$ and E=0.44.

- In Kerala, the Sakthikulangara/Neendakara harbour had significant landings of seahorse, brought along with the by-catch of shrimp trawling. Since there was no organised fishery or trade on seahorses this catch used to go unnoticed and wasted as manure among the by-catch.

- The species obtained from Kerala were *H. trimaculatus* and *H. borboniensis* consisting of smaller sized individuals of mean length 80 ± 0.78mm and mean wet weight 2.92 ± 1.61g. The landings were estimated as 1.6 MT wet weight per annum. Peak landings were observed in the month of November.

- The gut contents of *H. kuda* collected from Thondi were dominated by crustaceans (88.85%), consisting of copepods (22.8%), mysids and cumaceans (22.12%), amphipods and isopods (20.86%), decapod larvae and tiny caridean shrimps (20.67%). Semi-digested matter (8.56%) and inorganic sand (2.59%) formed the rest.

- The growth pattern of seahorses could not be found to follow the standard cubic form. The length-weight relationship for males and females of *H. kuda* collected from Thondi during 2001 was obtained as $\log W = -0.35792 + 1.103592 \log L$ or $W = 0.438615 (L^{1.103592})$, and $\log W = -0.43118 + 1.231822 \log L$ or $W = 0.370531 (L^{1.231822})$ respectively.

- Males with carrying brood pouch were seen in the catch from Thondi throughout the year, suggesting that seahorses in general or at least a few species seen in Palk Bay were year round breeders, the major breeding season extending from June to September with peak from July to August.

- The size at first maturity for males and females of *H. kuda* was found to be 66.07 mm and 77.99 mm for males and females respectively.

- The sex ratio of seahorses collected from Thondi remained more or less the same, except during the breeding season when more males were seen in the catches. In the landings of Sakthikulangara males were found to be 23.37% more than females.

- The ova of *H. kuda* are large, pear shaped and reddish. Ova diameter ranged from 0.5 - 0.8 mm and the mean fecundity was 56.8 g^{-1} body weight of the female. The hatch fecundity of the males were found to be 328-495 from a pregnant male (37.08 g^{-1}).

- The seahorse *H. kuda* has a unique breeding behaviour, where males and females form strictly monogamous pairs, reinforced by daily greetings. There are distinct phases in courtship behaviour namely brightening, quivering, pumping, pointing etc. that culminate in mating and egg transfer.

- Pregnancy of male *H. kuda* lasts for 18 to 20 days, until the release of the young ones, which resembled the adults in all respects. The hatching took place at night and early morning hours and in salinities ranging from 5 to 50 ‰, with no apparent difference in the time of hatching or the number of hatchlings obtained. The hatchlings were pelagic, free swimming and ranged in size from 7 - 8 mm.

- The captive rearing of the hatchlings of *H. kuda* using different feeds showed that a diet of enriched *Artemia* nauplii and mixed marine copepods was the best combination, which gave mean survival rates of up to 56% and growth of 49.4 mm and 0.316 g after 60 days of rearing.

- A stocking density of 3 juveniles per litre was found to be the optimum in captive rearing of *H. kuda*, which gave high growth increment in length (43.67 mm) and weight (0.313 g) as well as the highest mean production per litre of 1.51 during a rearing period of 60 days.

- The juveniles of *H. kuda* were found to grow equally well in salinities ranging from 15 ‰ to 35 ‰. The highest mean survival (60.56%), mean length (28.7 mm) and mean weight (39.1 mg) were obtained at 30 ‰ while rearing for 14 days.

- Illumination of the rearing tank was found to have a significant effect in improving the early juvenile survival of *H. kuda*. Rearing tanks, which were partially covered to improve the feeding efficiency of *Artemia* nauplli registered the highest mean survival (91%) and mean length (36.2 mm) and weight (66.14 mg) of juveniles during a 14-day rearing period.

- The juveniles of *H. kuda* were found to have reasonably high tolerance to extreme levels of salinity, pH and formalin.

- The LC_{50} values for low pH were obtained as 4.62, 4.83, 5.43 and 5.56 and that for high pH as 11.04,10.52,10.33 and 10.23 at 12, 24 48 and 72 h respectively.

- In the case of salinity, LC_{50} values of 1.59, 2.92, 3.63 and 4.67 ‰ for low salinity, and 58.08, 54.45, 51.29 and 49.26 ‰ for high salinity were obtained for 12, 24, 48 and 72 h respectively.

- The LC_{50} for formalin was found to be 315, 296.48, 279.25 and 271.02 ppm for 12, 24, 48 and 72 h respectively.

REFERENCES

REFERENCES

Abi-Ayed, A. and Kestemont, P., 1994. Comparison of the nutritional status of goldfish (*Carassius auratus*) fed with live, mixed or dry diet. *Aquaculture* 128: 163-176.

Anil, M. K., Kakati, V. S., Ganga, V. and Zacharia, S., 1999. Larval rearing of seahorse *Hippocampus kuda* under laboratory conditions. *Mar. Fish. Infor. Serv., T & E ser.,* 162: 23-25.

Alino, P., Cajipe, G. J. B., Ganzon-Fortes, E. T., Licuanan, W. R. Y., Montano, N. E. AND Tupas, L. M., 1990. The use of marine organisms in folk medicine and horticulture: a preliminary study. SICEN Leaflet 1, Marine Science Institute, University of the Philippines.

Anon, 1982. Culture of seahorse. In: Fish Biology and its Mariculture (In Chinese). Agriculture Publication Press, Beijing.

Anon, 1985. Pharmacopoeia of the People's Republic of China Vol.I. Pharmacopoeia Commission, Ministry of Health, PRC, Peoples' Medical Publishing House and Chemical Industry Press.

Anon, 1990a. Brief introduction to mariculture of five selected species in China. FAO/UNDP Reg. Sea farming Development and Demonstration Project, Bangkok (Thailand). 36 pp.

Anon, 1990b. Publicity and Education Committee, China's Aquaculture Society. In: Valuable Species Mariculture techniques. Science Publicity Press, Beijing (In Chinese), pp 123-142.

Anon, 1997. New Zealand Seahorse potential, *Fish Farm.Int.* 24(8): pp 37.

Anon, 1998. New Zealand Seashore project looks to sea cages, *Fish Farm.Int.* 25(7): pp 21.

Baldassano, P., 1996. A new feeding Strategy for *Hippocampus* sp., and other fishes. *The Journal of MaquaCulture*, 4(3). Online.

Barlow, G. W., 1984. Patterns of monogamy among teleost fishes *Arch. Fish. Eiss.* 35(1): 75-123.

Barlow, G. W., 1987. Spawning, eggs and larvae of the longnose filefish. *Oxymonacanthus longirostris,* a monogamous coralivore. *Env. Biol. Fish.* 20: 183-194

Barlow, G. W., 1988. Monogamy in relation to resources pp.55-79. In: C.N. Slobodchikoff (ed.). The Ecology of Social Behaviour

Baskerville-Bridges, B., Kling, L. J., 2000. Larval culture of Atlantic cod (*Gadus morhua)* at high stocking densities, *Aquaculture* 181: 61-69.

Clarke, E. and Pohle, J., 1992. Monogamy in the tile fish *Malacanthus latovittatus*, compared with polygyny in related species *Nat .Geog. Res, Exploration* 8:276-295.

Colson, D. J., Patek, S. N., Brainerd, E. L. and Lewis, S. M., 1998. Sound production during feeding in *Hippocampus* seahorses (Syngnathidae). *Exp. Biol. Fishes*.51:221-229.

Cornacchia, J. W., Colt, J. E., 1984. The effects of dissolved gas supersaturation on larval striped Bass, *Morone saxatilis* (Walbaum). *J. Fish Dis.* 7: 15-27.

Correa, M., Chung, K. S. and Manrique, R., 1989. Experimental culture of the seahorse *Hippocampus erectus. Biol. Inst. Oceanography* Venez (Boleti del Instituto Oceanografico de Venezuela, Cumana, 28 (1-2): pp 191-196.

Correa, M., Chung, K. S. and Manrique, R.,1996. Experimental culture of seahorse *Hippocampus erectus.* In: The Role of Aquaculture in World Fisheries: Proceedings of the World Fisheries Congress, Theme 6 (ed. Heggberget, T.G., Woiwode, J. G., Wolotira, R. J). Science Publishers, New Hampshire, pp.171-172.

D'Ancona, V., 1932. Famiglia: Syngnathidae. In: Uovo, Larvi e Stadi giovanilli di Teleostei. Fauna Flora Gets Napoli-Monog.38

Dao Xuan Loc and Hoang Phi 1991. Results of the surveys of *Hippocampus* seahorses in the coastal areas of the Central Provinces and the breeding of *Hippocampus kuda* seahorses in cement tanks. *Tuyen Tap Nghien Cuu Bien III*

Daniels, H. V. and Hodson, R. G., 1999. Weaning success of southern flounder juveniles: effect of changeover period and diet type on growth and survival. *N. Am. J. Aquac.* 61: 47-50.

Dawson, C., 1985. Indo-Pacific pipefishes (Red Sea to the Americas). Gulf Coast Research Laboratory, Ocean Springs, Mississippi, USA.

Do Huu Hoang, Truong Si Ky and Ho Thi Hoa, 1998. Feeding behaviour and food of seahorses in Vietnam. In: Proceedings of the Third International Conference on the Marine Biology of the South China Sea (ed. Morton, B.), Hong Kong University Press, Hong Kong, pp. 307-319.

Donaldson, T.J., 1989. Facultative monogamy in obligate coral-dwelling hawkfishes (Cirrihitidae). *Env. Biol. Fish.* 26: 295-302.

Downing, G., Litvak, M. K., 1999. The influence of light intensity on growth of larval Haddock. *N. Am. J. Aqua*.61: 135-140.

Drouin, M. A., Kidd, R. B. and Hynes, J. D., 1986. Intensive culture of lake white fish using *Artemia* and artificial feed. *Aquaculture*. 59: 107-118.

Dumeril, A. C., 1870. Histoire naturelle des posissons ou ichthyologie generale, Paris 2: 500-526.

Eastman, C. R., 1915. Olden time knowledge of *Hippocampus. Ann. Rept. Smith Inst.* 1915: 349-357.

Ehrlich, K. F., Cantin, M. C. and Rust, M.B., 1989. Growth and survival of larval and postlarval small mouth bass fed a commercially prepared dry feed and/or *Artemia* nauplii. *J. World Aquac. Soc.* 20: 1-6.

Emlen, S. T. and Oring, L. W., 1977. Ecology, sexual selection, and the evolution of mating systems. *Science* 197:215-223.

Eschmeyer, W. N. 1998. (ed.) Catalogue of fishes (Vol.1-3) special Publication no.1 of the Center for Biodiversity Research and Information. California Academy of Science, San Francisco, U.S.A.

Engstrom, K., 1963. Cone type and cone arrangement in teleost retina. *Acta. Zool.* 44: 179-243.

Fielder, K., 1954. Vergleichende Verhaltenstudien an Seenadeln, Schlangennadeln und Seepferdchen (Syngnathidae). *Z. fur Tierpsychol.* 11: 358-416.

Filleul, M. A., 1996. Optimising growth of juvenile big-bellied seahorse *Hippocampus abdominalis* Lesson B.Sc Honours thesis, University of Tasmania, Australia.

Finney, D. J., 1971. Probit Analysis. S. Chand and Co. Ltd. New Delhi, 3rd Edn., 333 pp.

Fish, M. P., 1953. The production of underwater sound by the Northern Seahorse *Hippocampus hudsonicus. Copeia* 1953: 98-99.

Flynn, A. J., Ritz, D. A., 1999. Effect of habitat complexity and predatory style on the capture success of fish feeding on aggregated prey. *J. Mar. Biol. Assoc.*, U.K. 487-494.

Forteath, N., 2000. Farmed seahorses-a boon to the aquarium trade. *INFOFISH International* 3/2000; pp 48-50.

Franzoi, P., Maccagnani, R., Rossi, R., Coeccherelli, V. U., 1993. Life cycles and feeding habits of *Syngnathus taenionotus* and S. *abaster* (Pisces, Syngnathidae) in a brackish bay of the Po River delta (Adriatic Sea). *Mar. Ecol. Prog. Ser.* 97, 71-81

Fritzsche, R. A., 1980. Revision of the Eastern Pacific Syngnathidae (Pisces: Syngnathiformes), including both recent and fossil forms. *Proc. Cal. Acad. Sci.* 42(6): 181-227.

Garrick-Maidment, N., 1997. Seahorses: conservation and care. Kingdom Books, England. 48 pp.

Gayanilo, F. C., Sparre, P. and Pauly, D., 2002. FiSAT II: FAO-ICLARM Stock Assessment Tools., FAO, Rome.

Gilbertson, D., 1987. The Midas Touch: Economic evaluation of technology development projects – *New Zealand J. Technology,* 3 (1): pp. 39-44.

Ginsburg, I., 1937. Review of the sea horses (*Hippocampus*) found on the coasts of the American continents and of Europe. *Proc. U.S. Nat. Mus.*83 (2997): 497-594.

Giwojna, P., 1996a. Seahorse Nutrition, Part II: Frozen Foods for Adults. *Freshwater and Marine Aquarium*, 19(11): 133-137.

Giwojna, P., 1996b. Seahorse Nutrition, Part III: Hand Feeding Adults. *Freshwater and Marine Aquarium* 19(12), 18-26.

Golani, D. and Fine, M., 2003. On the occurrence of *Hippocampus fuscus* in the eastern Mediterranean. *J. Fish Biol.*, 60(3): 764-766.

Gomon, M. F. and Neira, F. J., 1995. Syngnathidae : pipe fishes and seahorses. In: Larvae of temperate Australian fishes: Laboratory guide for larval fish identification (ed.) Neira, F. J., Miskiewicz, A. G. and Rinski, T. T. University of Western Australia press, Nedlands. Pp.122-132

Gomon, M. F., 1997. A remarkable new pygmy seahorse (Syngnathidae-*Hippocampus*) from South-eastern Australia with a redescription of *H. bargibanti* Whitley from New Caledonia – *Memoirs of the Museum of Victoria* 56(1): 245-253

Graham, N. D., 1953. Treasury of New Zealand fishes. Reed, Wellington.

Gronell, A. M., 1984. Courtship, spawning and social organisation of the pipe fish, Corythoichthys intestinalis (Pisces: Syngnathidea) with notes on two congeneric species *Z. Tierpsychol.* 65: 1-24

Gudger, E. W., 1906. The breeding habits and the segmentation of the egg of the pipefish, *Siphostoma floridae. Proc. U.S. Nat. Mus.*, 29(1431): 447-500.

Gunther, A. C., 1870. Catalogue of the fishes of the British Museum 8:198-206. Taylon and Francis, London.

Guthrie, D. M., 1986. Role of vision in fish behaviour. In: The behaviour of teleost fishes (ed.) Pitcher, T. J., London, *Croom Helm*. Pp. 75-113.

Gwynne, D. T., 1991. Sexual competition among females : What causes courtship-role reversal ? *Trends in Ecol. Evol.*6: 118-121.

Hardy, J. D., Jr., 1978. Development of fishes of the mid-Atlantic Bight: An atlas of egg, larval and juvenile stages.11 : Anguillidae through Syngnathidae. U.S.

Department of the Interior, U.S. Fish and Wildlife Services. FWS/OBS-78/12.

Harting, P., 1973. Preface to the Autobiography of Pieter Bleeker. In: Collected fish papers of Pieter Bleeker (ed. Lamme, W. H), Dr.W.Junk B. V., The Hague.

Hatcher, B. G., Johannes, R. E. and Robertson, A. I., 1989. Marine Ecosystems. *Oceanog. Mar. Biol. Ann. Rev.* 27: 337-414.

Haylor, G.S., 1991. Controlled hatchery production of *Clarias gariepinus* (Burchell 1822): growth and survival of fry at high stocking density. *Aquacul. Fish. Manage.*22: 405-422.

Herald, E. S., 1949. Pipefishes and seahorses as food for tuna. *Calif. Fish and Game* 35: 329.

Herald, E. S. and Rakowicz, M., 1951. Stable requirements for raising seahorse *Aqua J.* 22: 234-242

Herold, D. and Clark, E., 1993. Monogamy, spawning and skin-shedding of the sea moth, *Eurypegasus draconis* (Pisces: Pegasidae).*Envir. Biol. Fish.* 37: 219-236.

Hilomen-Garcia, g., 1999. AQD's marine ornamental fish project. *SEAFDEC Asian Aquac.* 21 (2): 31-38.

Home, M. L., 2001. A new species (Syngnathidae: *Hippocampus*) from the Great Barrier Reef. *Rec. Aus. Mus.* 53 (2). 243-246.

Hormchong, T., Komwech, V. and Kovitvadhi, S., (undated). Rearing of seahorse *Hippocampus kuda* (Bleeker) in laboratory. Burapha University Institute of Marine Science report 19/2529.

Hossain, M. A. R., Beveridge, M. C. M., Haylor, G. S., 1998. The effects of stocking density, light and shelter on the growth and survival of African catfish (*Clarias gariepinus* Burchell, 1922) fingerlings. *Aquaculture* 160: 251-258.

Hudson, L. L. and Hardy, J. D.,Jr., 1975. Eggs and larvae of the Atlantic seahorse *Hippocampus hudsonicus* (reclassified as *H. erectus).* University of Maryland CEES Ref.175-12 CBL.

Hsu, W. J., Chichester, C. O. and Davies, B. H. , 1970. The metabolism of β-carotene and other carotenoids in the brine shrimp, *Artemia salina* L. (Crustacea: Branchiopoda). *Comp. Biochem. Physiol.* 32: 69-79.

Huse, I., 1994. Feeding at different illumination levels in larvae of three marine teleost species: cod, *Gadus morhua* L., plaice, *Pleuronectes platessa* L., and turbot, *Scophthalmus maximus* (L.). *Aquacul. Fish. Manage.* 25: 687-695.

Ignatius, B., Rathore, G., Jagadis, I., Kandaswami, D. and Victor, A. C. C., 2000. Observations on captive spawning and rearing of seahorse *Hippocampus kuda. Mar. Fish. Infor. Serv., T & E ser.,* 163: 1-2.

Irwin, S., O'Halloran, J. O., FitzGerald, R. D., 1999.Stocking density, growth and growth variation in juvenile turbot, *Scophthalmus maximus* (Rafinesque), Aquaculture 178, 77-88.

James, P. L. and Heck, K. L., 1994. The effects of habitat complexity and light-intensity on ambush predation within a simulated seagrass habitat. *J. Exp. Mar. Biol. Ecol.* 176: 187-200.

Job, S. D., Do, H. H., Meeuwig, J. J., Hall, H.J. 2002. Culturing the oceanic seahorse, *Hippocampus kuda. Aquaculture* 214: 333-341.

Jones, A. G., Kvarnemo, C, Moore, G. I., Simmons, L. W., Avise, J. C., 1998. Microsatellite evidence for monogamy and sex-biased recombination in Western Australian seahorse *Hippocampus angustus. Mol. Ecol.* 7(11) pp 1497-1505.

Jordan, D. S. and Gilbert, C. H., 1882. Notes on fishes observed about Pensacola, Florida and Galveston, Texas with description of new species. Proceedings of the United States National Museum 56: 265-266.

Kaiser, H., Britz, P., Endemann, F, Kruger, D. P., Lockyear, J. F., Oellermann, L. K., Oliver, A. P., Rouhani, Q. and Hecht, T., 1997. Development of technology for ornamental fish aquaculture in South Africa. *S. Afr. J. Sci.* 93(8): 351-354.

Kaptchuk, T. J.,1983. *The web that has no weaver: Understanding Chinese Medicine.* Coughden and Weed, New York.

Kaup, J. J., 1856. Catalogue of the Lophobranchiate fish in the collection of the British Museum. Woodfall and Kinder, London.

Kolbeinshavin, A., Wallace, J. C., 1985. Observations on swim bladder stress syndrome in Arctic Charr *(Salvelinus alpinus)*, induced by inadequate water depth. *Aquaculture* 46: 259-261.

Kraul, S., Brittain, K., Cautrell, R., Nagao, T., Ako, H., Ogasawara, A. and Kitagawa, H., 1993. Nutritional factors affecting stress resistance in the larval mahimahi *Coryphaena hippurus. J. World Aquacult. Soc.*24, 186-193.

Kuronuma, K., 1961. A checklist of fishes of Vietnam. United States Operations Mission to Vietnam: Division of Agriculture and Natural Resources.

Lavens, P., Thongrod, S. and Sorgeloos, P., 2000. Larval prawn feeds and the dietary importance of Artemia. In: Freshwater prawn culture: the farming of *Macrobrachium rosenbergii* (ed. New, M.B. & Valenti, W.C). Oxford, Blackwell Science. P. 91-111.

Lawrence, C., 1998. Breeding seahorses – Facts and fallacies. *Western Fisheries*, 39-40, Autumn.

Leach, W.E. 1814. *Hippocampus trimaculatus. Zoological Miscellany* 1: 104 pp.

Lee, S. C.,1983. The family Synganthidae (Pisces: Syngnathiformes) of Taiwan. *Bull. Inst. Zoof. Acad. Sinica* 22(1): 67-82

Liang, B., 1992. Research on the culture of *Hippocampus. J. OCEAN UNIV. QINGADAO/QINGADAO AIYANG DAOXUE XUEBAO* 22(4): 39-44

Linnaeus, C., 1758. *Systema Naturae* (10th ed.)1: 338. Laurentii Salvii.

Linton, J. R. and Soloff, B. L., 1964. The physiology of the brood pouch of the male seahorse *Hippocampus erectus. Bull. Mar. Sci. Gulf Carib.*14(1):45-61.

Li Yue Cheng, 1994. *Zhong yao cai zhen wei jian bie cai se tu pu da quan* (Chinese Medicinal material: complete colour atlas for distinguishing real from false). Sichuan Science and Technology Publishing House. Cheagdu (in Chinese)

Lockyear, J., Kaiser, H., Hecht, T., 1997. Studies on the captive breeding of the knysna -seahorse, *Hippocampus capensis. Aquar. Sci. Conserv.* 1 (2):129-136.

Lockyear, J. F. Hecht, T., Kaiser, H., 2000. Studies on the captive culture of the Knysna seahorse, *Hippocampus capensis.* In: Land, Sea and People in the New Millennium. 10th Southern African Marine Science Symposium- Abstracts pp.1.

Longley, W. H. and Hildebrand, S. F., 1941. Systematic catalogue of the fishes of Tortugas, Florida. *Papers Tortugas Lab., 34, Carnegie Inst. Wash. Publ.*535: 331 pp.

Lourie, S. A., Vincent, A. C. J. and Hall H.J., 1999a. Seahorses; an identification guide to the world species and their conservation. Project Seahorse, London, UK. 214 pp.

Lourie, S. A., Pritchard, J. C., Casey, S. P., Si Ky Truong, Hall, H. J. and Vincent, A. C. J., 1999b. *The Taxonomy of Vietnam's exploited seahorses (Family: Syngnathidae), Biol. J. Linn. Soc.* 66:231-256

Lovett, J. M., 1969. An introduction to the biology of the seahorse *H. abdominalis.* B.Sc Honours thesis, University of Tasmania, Australia. 102 pp.

Lu, J., Li, B., Sun, Y., Yang, D. and Huang, K., 2002. the ingestion, growth and ecological conversion efficiency of *Hippocampus kuda* under intensive rearing conditions., *J. Fish. China; Shuichan Xuebao*. 26(1): 61-66.

Lunn, K. E. and Hall, H. J., 1998. Breeding and management of seahorses in aquaria. In: Briefing Documents for the First International Aquarium Workshop on Seahorse Husbandry, Management, and Conservation. Project Seahorse, Chicago, 98 pp.

Marco, R. D., 2003. What has ten legs and improve your complexion ? A new food source for fresh and marine fish. Freshwater and Marine Aquarium Magazine.1(2): pp.86 - 92.

Marichamy, R., Lipton, A. P., Ganapathy, A. and Ramalingam, J. R., 1993. Large Scale exploitation of seahorse (*Hippocampus kuda*) along the Palk Bay Coast of Tamil Nadu. *Mar. Fish. Infor. Serv., T & E ser., 119:17-20.*

Martin-Robichaud, D. J., Peterson, R. H., 1998. Effects of light intensity, tank colour and photoperiod on swimbladder inflation success in larval striped bass, *Marone saxatilis* (Walbaum). *Aqua. Res.*29: 539-547.

Maruthanayagam, C. and Subramaniam, P., 200. Diversity of copepods in Palk Bay and Gulf of Mannar along the southeast coast of India. *Sheshaiyana*, 8 (2): 13-14.

Masonjones, H. D. and Lewis, S. M.,1996. Courtship behaviour in the dwarf seahorse *Hippocampus zosterae*. *Copeia* (3): 634-640.

Masonjones, H. D., 1997. Sexual selection in the dwarf seahorse H*ippocampus zosterae* (Syngnathidae): An investigation into the mechanism determining the degree of male v/s female intra sexual competition and inter sexual choice. Ph.D.thesis. Tufts University, USA.

Masonjones, H.D., 2001. The effect of social context and reproductive status on the metabolic rates of dwarf seahorses (*Hippocampus zosterae*). *Comp. Biochem. Physiol.,A* 129(2-3): pp.541-555.

Masonjones, H. D. and Lewis, S. M., 2000. Differences in potential reproductive rates of male and female seahorses related to courtship roles. *Anim. Behav.*, 59: 11 - 20.

McAllister, D. E., 1990. Working list of the fishes of the world.

McEvoy, L. A., Naess, T., Lie, O., 1998. Lipid and fatty acid composition of normal and malpigmented Atlantic halibut (*Hippoglossus hippoglosus)* fed enriched *Artemia*: a comparison with fry fed wild copepods. *Aquaculture* 163: 237-250

MPEDA., 2003. Statistics of Marine Products Exports, 2001. MPEDA. 83 pp.

Munro, I. S. R., 1958. Syngnathiformes-Handbook of Australian Fishes. Fisheries Newsletter 17 (2-5):81-96

Naas, K., Huse, I, Iglesias, J., 1996. Illumination in first feeding tanks for marine fish larvae. *Aquacult. Eng.* 15 (4):291-300.

Nash, C. E., Kuo, C. M., Madden, W. D. and Paulsen, C. L., 1977. Swim bladder inflation and survival of *Mugil cephalus* to 50 days. *Aquaculture* 12: 89-94.

Nguyen Khae Huong, 1993. The marine fish in Vietnam, Vol.2, Hanoi Science Technology Publishing House, pp. 60-75.

Orians, G. H., 1969. On the evolution of mating systems in birds and mammals. *Amer. Nat.* 103: 589-603.

Pauly, D., 1980. On the interrelationship between natural mortality, growth parameters and mean environmental temperatures in 175 fish stocks. *J. Cons. CIEM.* 39 (3): 175-192.

Pauly, D., 1983., Length-converted catch curves: a powerful tool for fisheries research in the tropics (Part II). *Fishbyte* 2 (1): 17-19.

Paxton, J. R., Hoese, D. F., Allen, G. R. and Honely, J. E., 1989. Syngnathidae. In: Zoological Catalogue of Australia. 7: Pisces, Petromyzontidae to Carangidae (ed. D. W. Walton and R. Logmore): pp. 412-433.

Payne, M. F., Rippingale, R. J. and Longmore, R. B., 1998. Growth and survival of juvenile pipefish(*Stigmotopora argus)* fed live copepods with high and low HUFA content. *Aquaculture* 167: 237-245.

Payne, M. F. and Rippingale, R. J., 2000. Rearing West Australian seahorse, *H. subelongatus,* juveniles on copepod nauplii and enriched *Artemia. Aquaculture* 188: 353-361.

Perante, N. C., Pajaro, M. G., Meeuwig, J. J. and Vincent, A. C. J., 2002. Biology of a seahorse species, *Hippocampus comes* in the Central Philippines. *J. Fish Biol.* 60: pp 821-837.

Pham, T. M., 1993. Raising the seahorse *Hippocampus kuda. Russ. J. Mar. Biol, Biol, Biol. Morya/Mar Biol* .18 (5-6): 203-205.

Pham, T. M., Kornienko, E. S. and Drozdov, A. L., 1998. Embryonic and larval development of the seahorse *Hippocampus kuda. Biol. Morya/ Mar. Biol.* 24 (5): 315-418.

Pietsch, T. W., 1978. Evolutionary relationship of the seamoth (Teleostei, Pegasidae) with a classification of gaterosteiform families. Copeia 1978: 517-529.

Pietsch, T. W. and Anderson, W. D., Jr., 1997. Collection building in ichthyology and herpetology. Special Publication No.3, American Society of Ichthyologists and Herpetologists.

Planas, M., Cunha, I., 1999. Larviculture of marine fish: problems and perspectives. *Aquaculture* 177: 171-190.

Pollard, D. A., 1984. A review of ecological studies on seagrass-fish communities, with particular reference to recent studies in Australia. *Aquat. Bot.* 18: 3-42.

Prein, M., 1995. The Aquaculture Potential of Seahorses and Pipe fishes. *INFOFISH Intl.* 6/1995: 35-38

Rangaswamy, P., 1995. A Text Book of Agricultural Statistics. Wiley Eastern. 496pp.

Rauther, M., 1925. Die syngnathiden des Golfes von Neapel. Fauna u.Flora Neapel.36: 1-365. Cited in Vincent, A. C. J., 1990. Reproductive ecology of seahorses. Ph.D. thesis. University of Cambridge, UK.

Raymont, J. E. S., Sreenivasagam, R. T. and Raymont, J. K. P., 1971. Biochemical studies of Marine Zooplankton VIII. Further investigation on *Meganyctiphanes norvegica* (M. sars.). *Deep Sea Res.*, 18: 1167 - 1178.

Raymont, J. E. S., 1983. Plankton and Productivity in the Oceans. Vol. 2. Zooplankton. Pergamon Press. Oxford. 423 pp.

Reid, G. K., 1954. An ecological study of the Gulf of Mexico fishes, in the vicinity of Cedar Key, Florida. Bulletin of Marine Science of the Gulf and Caribbean. 4 (1): 1-94.

Reina-Hervas, J. A., 1989. Contribucion al estudio de la F. Syngnathidae en las costas del sureste de Espana. *Arquivios do Museu Bocage* 121: 325-334.

Ridley, M., 1978. Paternal care. *Anim. Behav.*26: 904-932.

Rosenlund, G., Stoss, J. and Talbot, C., 1997. Co-feeding marine fish larvae with inert and live diets. *Aquaculture.* 155:183-191.

Roule, M. L., 1916. Description de l' *Hippocampus aimei.*sp. nov., espece nouvelle d'eau douce, provenant du Mekong. Bull. Mus. Nat. Hist. Paris. 22:11-13.

Sargent, J. R., McEvoy, L. L., Bell, J. G., 1997. Requirements, presentation and sources of polyunsaturated fatty acids in marine fish larval feeds. *Aquaculture* 167, 237-245.

Schiotz, A., 1972. Collins Guide to Aquarium Fishes and Plants. Collins, London.

Schroeder, R. E.,1980. Philippine Shore Fishes of the Western Sulu Sea. NMPC, Manila.

Selmen, K., Wallace, R. A. and Player, D., 1991. Ovary of the seahorse *Hippocampus erectus. J. Morphol.* 209: 285-304

Shen, S-C., 1993. Fishes of Taiwan. 383 pp.

Snedecor, G. W. and Cochran, W. G., 1967. Statistical Methods. Oxford and IBH Publishing Co., New Delhi, 6th Edn., 593 pp.

Sorgeloose, P. and Pandian, S. K., 1984. Production and use of *Artemia* in aquaculture. CMFRI spl. Publ. (15): 74 pp.

Sparre, P., Ursin, E. and Venema, S. C., 1989. Introduction to tropical fish stock assessment. FAO Fish, Tech. Paper., 306 (1). FAO, Rome. 337 pp.

Sreepada, R. A., Desai, U. M., Naik, S., 2002. The plight of Indian seahorses: need for conservation and management, *Curr. Sci.* 82 (4)pp.377-378.

Strawn, K., 1958. Life History of Pigmy seahorse *Hippocampus zosterae* Jordan & Gilbert, at Cedar Key, Florida, *Copeia* : 16-22

Suresh, A. V., Lin, C. K., 1992. Effect of stocking density on water quality and production of Red Tilapia on seed production in a recirculated water system. *Aquac. Int.* 5: 207-216.

Svensson, I., 1988. Reproductive costs in two sex-role reversed pipefish species (Syngnathidae). *J. Anim. Ecol.* 57:929-942.

Teixeira, R. L, Musick, J. A, 1995. Trophic ecology of two congeneric pipefishes (Syngnathidae) of the lower York River, Virginia. Environ. Biol. Fishes 43, 295-309.

Teixeira, R. L and Musick, J. A, 2001. Reproduction and food habits of the lined seahorse, *Hippocampus erectus* (Teleostei: Syngnathidae) of Chesapeake Bay, Virginia. *Revue of Brasilian Biology* 61 (1): 79-90.

Thornhill, R. and Gwynne, D., 1986. The evolution of sexual differences in insects. *Amer.Sci.*74: 382-389.

Thresher, R. E., 1984. Reproduction of reef fishes. T.F. H. Publications, Neptune City.399pp.

Tipton, K. and Bell, S. S., 1988. Foraging patterns of two syngnathid fishes: importance of harpacticoid copepods. *Mar. Ecol. Prog. Ser.* 47: 31-43.

Trivers, R. L., 1972. Parental investment and sexual selection. In: Sexual selection and the descent of man (ed. Campbell, B) Aldine Publishing Company, Chicago, pp.136-179.

Trivers ,R. L., 1985. Social evolution. Benjamin Cummings Publishers, Menlo Park, CA.

Truong Si Ky and Doan Thi Kim Lam 1994. Reproduction of seahorses (*Hippocampus kuda)* Collection of Marine research works Vol.111-120 (in Vietnamese)

Truong, S. K., 1998. Prospects of community based seahorse aquaculture in Vietnam. In: The Marine Biology of the South China Sea III (ed. Morton, B), Hong Kong University Press, Hong Kong, pp.465-474.

Vari, R., 1982. Fishes of the western North Atlantic, subfamily Hippocampinae. The seahorses. Sears Foundation for Marine Research Memoir, Yale University, USA. 1(8): 173-189.

Vincent, A., 1990. A seahorse father makes a good mother. Natural History 12: 34-42.

Vincent, A. C. J., Ahnesjo, I., Berglund, A. and Rosenquist, G.,1992. Pipefishes & Seahorses : are they all sex role reversed? *Trends Ecol. Evol.* 7: 237-241.

Vincent, A. C. J., 1994a. The improbable seahorse, National Geographic October,1994. pp.126-140.

Vincent, A. C. J., 1994b. Seahorses exhibit conventional sex roles in mating competition, despite male pregnancy. *Behaviour* 128 (1-2):135-151.

Vincent, A. C. J., 1994c. Operational sex ratios in seahorses. *Behaviour* 128 (1-2):153-167.

Vincent, A. C. J., 1995a. A role for daily greetings in maintaining seahorse pair bonds. *Anim. Behav* 49:258-260.

Vincent, A. C. J., 1995b. Exploitation of seahorses and pipe fishes – *NAGA*.18(1): 18-19.

Vincent, A. C. J., 1995c. Trade in seahorses for traditional Chinese medicines, Aquarium fishes & curios. Traffic Bulletin.15 (3): 125-128.

Vincent, A.C.J., 1995d. Seahorse Keeping. The *Journal of MaquaCulture*, 3(1). Online.

Vincent, A. C. J. and Sadler, L. M., 1995. Faithful pair bond in wild seahorses, *H. whitei. Anim. Behav,* 50:1557-1569.

Vincent, A. C. J., 1996. The International Trade in seahorses. TRAFFIC International, Cambridge (UK). 163 pp.

Vincent, A. C .J. and Pajaro, M. G., 1997. Community based management for sustainable seahorse fishery. In. Developing and sustaining World fisheries resources. The State of Science & Management., (ed. Hancock D.A, Smith D.C), CSIRO, Colling Wood, World Fisheries Congress, Brisbane (Australia), pp. 761-766.

Vincent, A. C. J., 1998. Seahorse culturing. *Australia Aquaculture*. 11(5): 72-123.

Vincent, A. C. J. and Giles, B. G., 2003. Correlates of reproductive success in wild population of *Hippocampus whitei*. *J. Fish Biol.*63(2), pp344

Wallace, J. C., Kolbeinshaven, A. G. and Reinsnes, T.G., 1988. The effects of stocking density on early growth in Arctic charr, *Salvelinus alpinus* (L.). *Aquaculture* 73, 101-110.

Wallace, R. A. and Selman, K., 1981. Cellular and dynamic aspects of oocyte growth in teleosts. *Amer. Zool.* 21: 325-343

Wang, N., Hayward, R. S., Noltie, D. B., 2000. Effects of social interactions on growth of juvenile hybrid sunfish held at two densities. *N. Amer. J. Aquac.* 62: 161-167.

Watanabe, T., Kitajima, C., Fujita, S., 1983. Nutritional values of live organisms used in Japan for mass propagation of fish: a review. *Aquaculture* 34: 115-143.

Weitkamp, D. E., Katz, M., 1980. A review of dissolved gas supersaturation literature. *Trans. Am. Fish. Soc.* 109: 659-702.

Whitfield, A. K., 1995. Threatened fishes of the world: *Hippocampus capensis* Boulenger, 1900 (Syngnathidae) *Env. Biol. fishes* 44: 362pp.

Whitley, G. and Allen, J., 1958. The seahorse and its relative, Griffin Press, Melbourne. 55 pp.

Wickler, W and Seibt, U., 1981. Monogamy in crustacea and man. Z. Tierpsychol. 57: 215-234.

Williams, G. C., 1966. Adaptation and natural selection. Princeton University Press, Princeton, 307pp.

Williams, G. C., 1975. Sex and evolution. Princeton Univ. Press, Princeton, NJ.150 pp.

Wilson, M. J. and Vincent, A. C. J., 1998. Preliminary success in closing the life cycle of exploited seahorse species, *Hippocampus* spp., in captivity. *Aquat. Sci. Conserv. 2, 179-196.*

Wittenberger, J. F. and Tilson, R. L., 1980. The evolution of monogamy: hypotheses and evidence. *Ann. Rev. Ecol. Syst.* 11: 197-232.

Wong, T. W., Wong, S. L. and Donnan, S. P. B.,1993. Traditional Chinese Medicines in Hong Kong: a comparison of the consultation process and side effects. *J. Hong Kong Med. Assoc.* 45

Woods, C. M. C., 2000a. Improving initial survival in cultured seahorses, *H. abdominalis* Leeson, 1827 (Teleostei: Synganthidae), *Aquaculture* 190: 377-388.

Woods, C. M. C., 2000b. Preliminary observations on breeding and rearing the seahorse, *Hippocampus abdominalis* (Teleostei: Syngnathidae) in captivity. *N.Z.J. Mar. Freshwater Res.* 34: 475-485.

Xu, G. Z., 1985. Fish mariculture studies in China. ICLARM Newsletter,8(4): 5-6.

Yearsley, G. K., Last, P. R. and Morris, G. B., 1995. The modified and upgraded species-coding system for Australian fisheries databases. Final report to Fishing Industry Research and Development Trust Fund, Project 90/105, 250 pp.

Zhang, Chaohui; Xu, Guojun; Xu, Luoshan and Wang Qiang, 1996. Seahorse culture in China. J. *Zhenjiang Coll. Fish/Zhenjiang Shuichn Xueyuan Xuebao,* 15(3): 216-220.

Zhang, Feng, Wang and Gueon, 1999. The observations on the histology of the pituitary gland of seahorse (*H. japonics*) J. *Dlian Fish. Coll./Dalian Shuichan Xueyuan Xuebao, Dalian* , 6 (3-4) : 28-34.