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The commercial fishery for ocean leatherjackets (*Nelusetta ayraudi*, Monacanthidae) in New South Wales, Australia.

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Abstract

The ocean leatherjacket (*Nelusetta ayraudi*) has a long history of commercial exploitation in New South Wales, Australia. Records of reported landings indicate that substantial peaks of between 600 and 900 tonnes per annum occurred during the 1920s and again during the 1950s. These peaks were followed by large declines, which suggest that this species is vulnerable to over-exploitation. In recent years from 2000/01 to 2006/07, annual commercial landings of ocean leatherjackets using oceanic demersal fish traps and demersal otter trawl have increased from 134 to 430 tonnes. Between 2003 and 2005 ocean leatherjackets in commercial landings ranged approximately between 22 and 65 cm in total length. Ocean leatherjackets were fully recruited to the fishery at two years of age, with the majority of the catch (83%) aged either two or three years. The instantaneous total mortality rate was estimated from an age-based catch curve as 1.1. Natural mortality was estimated as approximately 0.5, based on a maximum age of 6 years. Yield per recruit indicated that under current levels of exploitation the yield per recruit would be maximized at a length at first harvest of 35 cm in total length.

Introduction

Monacanthids, commonly referred to as 'filefish' and 'leatherjackets', are harvested in large quantities throughout the world. Major fisheries exist throughout Asia in coastal waters of Japan, Korea, China, Vietnam and Taiwan (Murakami and Onbe 1967; Kakuda 1976; 1978; Shiqin and Hu Yachu 1980; Park 1985; Kawase and Nakazono 1994; Minquan 1994; Chen et al. 1997; Wei-Zhong et al. 1998; Daug 2002; FAO 2004; 2006). Smaller fisheries also exist in Chile, Antigua Barb (Caribbean), Ukraine, New Zealand (FAO 2004; 2006), the Canary Islands region (Mancera-Rodriguez and Castro-Herandez 2004) and Australia (Lindholm 1984; Grove-Jones and Burnell 1991; Kailola et al. 1993). In Australian waters the majority of leatherjackets are taken from the southern half of the continent (below 30ºS) in cooler temperate waters using

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commercial fishing methods such as demersal fish and prawn trawls, traps, seines and gillnets, as well as by hook and line by commercial and recreational fishers. Australia contains the highest diversity of monacanthids in the world, with a total of 59 species being recorded (Hoese et al. 2006). The ocean leatherjacket (*Nelusetta ayraudi*) is one the largest monacanthids in the world and is the dominant monacanthid species harvested from Australian waters (Kailola et al. 1993).

There has been a long history of exploitation of ocean leatherjackets in New South Wales (NSW) waters off the southeastern coast of Australia, with the first catches in the Sydney Fish Markets recorded in March 1884 (Klaer, 2001). The ocean leatherjacket fishery increased greatly at the turn of the 19th century with the introduction of steam trawlers to offshore fishing grounds with annual catches increasing to 682 tonnes by 1922 (Klaer, 2001). Today, the largest fisheries for ocean leatherjackets are in South Australia and NSW, with catches in each state usually exceeding 400 tonnes (unpublished data). The majority of ocean leatherjackets in these states are taken using demersal fish traps (Stewart & Ferrell, 2003), however large catches are also taken by demersal trawls. In NSW, ocean leatherjackets are the 2nd most valuable species within the demersal trap fishery, behind snapper (*Pagrus auratus*) (NSW Department of Primary Industries catch records). The fishery for ocean leatherjackets extends the length of the coast of NSW, with the fishing season varying with latitude. Fish are targeted on the southern NSW coast during summer and autumn, while it is a winter fishery on the far northern NSW coast.

The management of monacanthid fisheries in Australia, specifically those for ocean leatherjackets, has been limited by a lack of knowledge of their biology and the composition of sizes or ages in landings. In NSW, there are no specific management regulations for harvesting ocean leatherjackets. Rather, catches are controlled through general gear regulations in the multispecies demersal trap and trawl fisheries. There is currently no regulated minimum legal length for ocean leatherjackets or any other leatherjacket species. Given that monacanthids, and particularly ocean leatherjackets, are considered vulnerable to overfishing, the aim of this paper is to provide the first comprehensive description of the fishery for ocean leatherjackets in NSW and therefore, enable improved management of the fishery. Specifically, we: (i) describe trends in historical landings and the sizes and ages in commercial landings; (ii) use catch composition data in association with biological information to estimate instantaneous mortality rates through catch curve analysis; and (iii) model yield per recruit to estimate the optimal size at first harvest. Finally, we make recommendations for improved management of the ocean leatherjacket fishery in NSW based on these results.

Materials and methods

Information on historical catch records was obtained from the NSW Department of Primary Industry catch records database from 1940 onwards. These records are supplied by commercial fishers as a regulated requirement of their fishing licences, and provide information such as species captured, quantities retained, areas fished and, since 1997, the methods used. Reported catch weights of ocean leatherjackets generally refer to trunk weights (i.e., after all fish are headed and gutted).The lengths of a total of 4383 ocean leatherjackets landed by the commercial demersal trap fishery in NSW between 2003 and 2005 were measured either at the Sydney Fish Markets, regional fishermen's cooperatives or onboard commercial fishing vessels. All fish were measured as total length (TL), to the nearest whole centimetre below the true length.

Estimates of the age compositions in the commercial landings of ocean leatherjackets were derived from the estimated ages of fish sampled during 2003 and 2004. Ocean leatherjackets were representatively sampled each month from commercial catches and an estimate of the age of each of these sampled fish was made by counting opaque zones in sectioned otoliths (Miller, 2007).

Estimates of instantaneous total mortality (Z) were made from the slope of the descending arm of the catch curve (i.e. by fitting a regression to the natural logarithm of age frequency against age for all fully recruited age classes). An estimate of natural mortality (M) was made after the method of Hoenig (1983) for exploited populations based on either 1% or 5% attaining the maximum age for the species, where the maximum reported age for ocean leatherjackets is approximately 6 years (Miller 2007). Estimates of fishing mortality (F) were made by subtracting the estimates of M from Z.

Yield per recruit analysis (YPR) was done using a variant of the Beverton & Holt (1957) model described in www.fishbase.org as case III. The model describes YPR in terms of exploitation rate (E = F / Z) and size at first capture (length at capture / L_∞). This approach was used because in the present study we required information that was related to fish length rather than age. Input parameters included the von Bertalanffy growth function parameters $L_\infty = 88.5$ cm, $k = 0.16$ year^{-1}, $t_0 = -0.57$ years (Miller, 2007) and estimates of mortality rates.

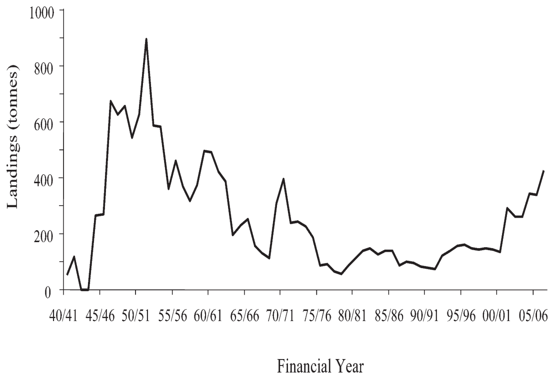

Figure 1. Historical commercial landings of ocean leatherjackets in New South Wales.

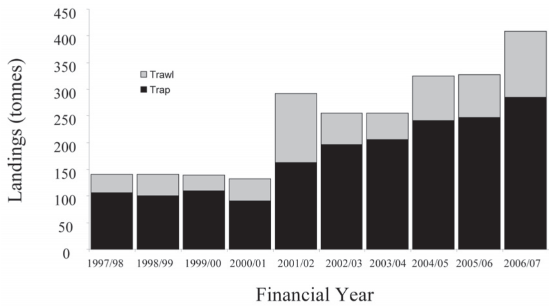

Figure 2. Landings of ocean leatherjackets by demersal trap and demersal trawling fisheries in New South Wales since 1997/98.

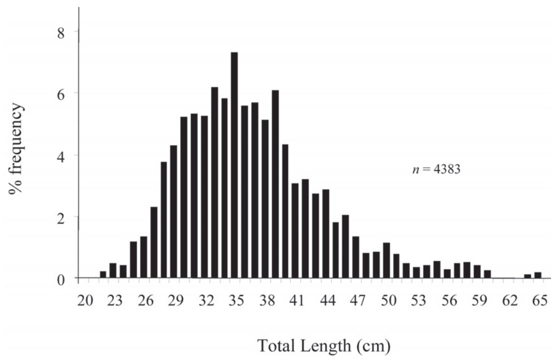

Figure 3. The sizes of ocean leatherjackets landed by the New South Wales demersal trap fishery between 2003 and 2005.

Results

Historical records show that commercial landings of ocean leatherjackets in NSW in the early 1950s increased to levels of those experienced in the early 1920s (Klaer 2001) (Fig. 1). In 1951/1952, a total of 900 tonnes of leatherjackets were reportedly captured. A breakdown of fisheries contributing to the capture of the largest records identified a developing demersal trap fishery in the north of the state, which captured 480 tonnes. Catches declined to 318 tonnes in 1957/1958, with further declines observed in 1968/1969 to 112 tonnes and 56 tonnes by 1978/1979. In recent years, however, catches of ocean leatherjackets have steadily increased from 134 tonnes in 2000/01 to 430 tonnes during 2006/07 with the latter having an estimated value of AUD$1.1 million market value. Catches of ocean leatherjackets have increased in both of the major fishing sectors (trap and trawl) since 1997/98, with an aver age of 73% of the annual catch being captured using fish traps (Fig. 2).

The sizes of ocean leatherjackets in commercial trap catches between 2003 and 2005 ranged between 22 and 65 cm, and had a median size of 36 cm (Fig. 3). The age composition of landi ngs showed that ocean leatherjackets were fully recruited at 2 years of age (Fig. 4). The bulk of the fishery (83%) consisted of fish aged 2 and 3 years old.

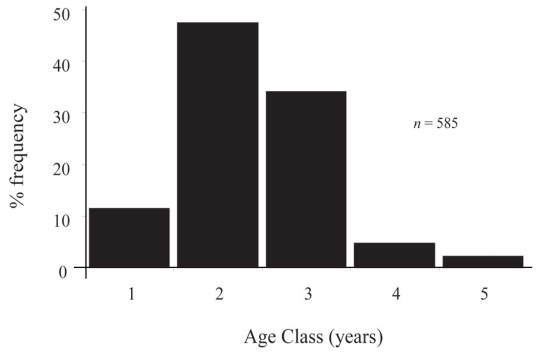

Figure 4. The age composition of ocean leather jackets in landings of the New South Wales demersal trap fishery during 2003/04.

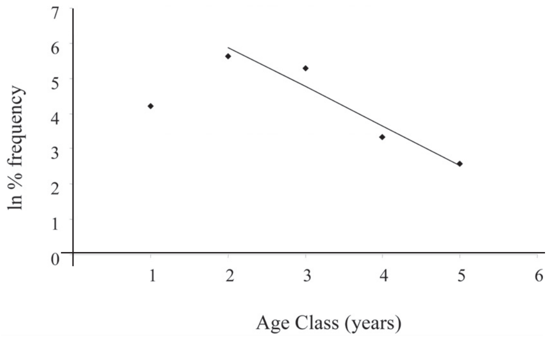

Figure 5. Catch curve for ocean leatherjackets from 2003 to 2004.

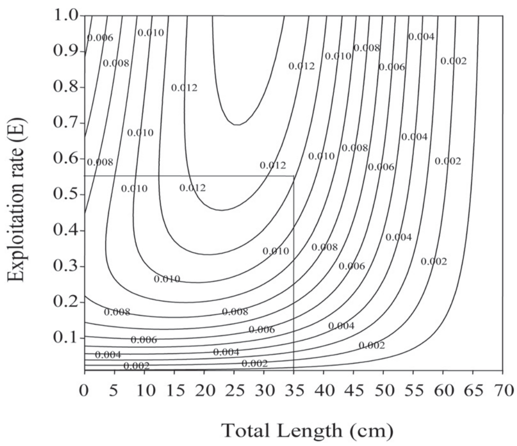

Figure 6. Yield per recruit isopleths for ocean leatherjackets. The lines indicate the current level of exploitation rate and the corresponding length at which the yield per recruit is maximized.

The estimate of Z made from the descending arm of the catch curve for ocean leatherjackets aged between 2 and 5 years old was 1.1 (Fig. 5). The estimate of M based on either 1% or 5% of fish attaining the maximum age of 6 years ranged between 0.50 and 0.77. Due to the relatively short nature of the study and the fact that ocean leatherjackets are reported to attain larger sizes (70 cm - Hutchins & Swainston, 1999) than we observed (65 cm), it was assumed that ocean leather jackets can attain ages of greater than 6 years. Given this, we believe that the more realistic estimate of M is based on 5% of fish attaining 6 years old (M = 0.50) and therefore the most probable estimate of F = 0.6 (1.1 – 0.5) and exploitation rate (E) = 0.55.

The yield per recruit analysis indicated that at the most probable level of current exploitation the yield per recruit of ocean leatherjackets is maximized at 35 cm (Fig. 6). Using less precautionary (lower) estimates of M resulted in the yield per recruit being maximized at slightly smaller sizes.

Discussion

Monacanthids are captured in very large numbers in commercial fisheries throughout Asia primarily by large stern fish trawling vessels. In contrast, commercial fisheries for monacanthids in Australia are relatively small, with the majority of the catch captured by either small-scale demersal fish trawls or demersal fish traps in the southern half of the continent. Nevertheless, the fishery for ocean leatherjackets in NSW is extremely important locally and so the information provided in this paper should be carefully considered when formulating future improvements to the fisheries management strategies for those fishing methods.

Historical catch information suggests that the ocean leatherjacket stock in NSW was fished down during the 1920s (Klaer, 2001) when they were heavily targeted by steam demersal trawlers, and again during the 1950s as a result of trawling operations and a developing trap fishery. These factors indicate that although current landings are increasing, ocean leatherjackets are vulnerable to overfishing and that any further increases in effort may cause stock declines.

The sizes of ocean leatherjackets landed by commercial fishers in NSW indicate that much of the catch is of juvenile sized fish (< 35 cm) (Figure 4). Currently, fishers in the oceanic demersal trap fishery must use 50 mm hexagonal wire mesh in their traps. These traps have been demonstrated to be highly size-selective for ocean leatherjackets, but would retain almost all fish > 25 cm in total length (Stewart & Ferrell, 2003). However, the introduction of escape panels of 50 x 75 mm welded mesh, which are to be made compulsory in fish traps in NSW by late 2008, most likely will result in traps selecting ocean leatherjackets at sizes > 35 cm in total length (their size at sexual maturity - Miller, 2007).

The age composition of ocean leatherjackets in the NSW demersal trap fishery was found to be similar to those reported in other monacanthid fisheries in Australia and around the world with the majority of fish captured between two and five years old and the oldest fish not exceeding 10 years (Kakuda, 1979; Chien and Hu, 1980; Park 1985; Grove-Jones and Burnell, 1991; Peristiwady and Geistdoerfer 1991; Chen et al. 1998; Mancera-Rodriguez and Castro-Hernandez, 2004). This emphasises that globally, monacanthids have fast growth rates and so become vulnerable to capture from an early age.

The estimates of mortality rates indicated that M was similar to F and therefore that the current exploitation rate was approximately 0.5 which is generally considered to be sustainable (Gulland, 1970). The yield per recruit analysis indicated that yield could be improved if the size at first harvest for ocean leatherjackets was increased to 35 cm. Although the implementation of escape panels of larger mesh will in turn select ocean leatherjackets at approximately 35 cm (Stewart & Ferrell, 2003), there are currently no regulated restrictions on the sizes of ocean leatherjackets able to be retained. The information presented here may therefore, assist managers in the consideration of a minimum legal length on ocean leatherjackets as an appropriate management tool.

In NSW, both recreational and trawl fishers catch substantial quantities of small ocean leatherjackets and a minimum legal length may help to protect these juveniles. Although, there are currently no estimates of discard mortality for ocean leatherjackets, discard mortality may be high as ocean leatherjackets suffer from barotrauma-related injuries being surfaced from relatively shallow (< 30 m) depths and they may also be damaged during trawling (pers. obs.). Research is needed to investigate the rates of mortality of discards from demersal trawling and trapping operations.

The level of protection of populations of ocean leatherjackets in NSW has increased with the introduction of area-closures through the past ten or so years. These area closures include recreational fishing havens, marine protected areas such as marine parks, aquatic reserves and marine components of national parks and nature reserves. Given that ocean leatherjackets appear to be vulnerable to over-exploitation, it will be important to maintain these area closures in years to come. In addition, continued monitoring of the sizes and ages in landings is required so as to assess changes in population structure resulting from the currently increasing level of exploitation.

Acknowledgements

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Reproductive Aspects of the Black Pomfret, *Parastromateus niger* in the Kuwaiti Waters of the Arabian Gulf

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Abstract

The reproductive activities of the male and female black pomfret *Parastromateus niger* in Kuwaiti waters were investigated from October 2003 to September 2005. Analysis of seasonal variations in the gonadosomatic index (GSI) during the two-year study period revealed high values from February to September, suggesting that the black pomfret has a prolonged spawning season, from February to September. GSI fluctuations correlated positively with rising water temperatures in Kuwait from low values in both parameters in January to high values in February/March ($r = 0.836$, $p<0.05$ for males and $r = 0.764$, $p<0.05$ for females), suggesting that temperature plays a role in triggering spawning in both the sexes. Analysis of seasonal distribution of maturity stages for the two years revealed the presence of ripe/running males and females from February to September, thus confirming the spawning periodicity revealed through the analysis of fluctuations in the GSI. Macroscopic and microscopic studies of maturity stages revealed six stages in the males and seven in the females. The logistic function based on pooled data for the two years revealed that the minimum size at sexual maturity (L_{50}) was attained at a size of 30.9 cm SL in males ($r^2 = 0.284$) and 36.5 cm SL in females ($r^2 = 0.355$). The ratio of males to females in monthly samples did not depart significantly from the hypothetical 1:1 during the entire study period (÷2 = 61.9, d.f. = 11, p< 0.05). Total fecundity ranged from 71 305 in a fish measuring 39.8 cm SL and weighing 1 572.5 g, to 3 895 449 in a 49 cm SL and 2 630 g fish, with a mean of 1 216,734 eggs. Positive correlations were found between fecundity and ovary-free body weight, standard length and ovary weight, and a negative one with egg size. The average relative fecundity was 948 eggs/g ovary-free body weights, which was neither a function of fish standard length nor ovary-free body weight.

Introduction

The black pomfret, *Parastromateus niger* (Carangidae), locally called *Halwayah*, is widely distributed in coastal waters of India (Sivaprakasam 1965; Rao 1973; Pati 1983; Kulkarni et al. 1991), in the Sea of Japan (Yukio et al. 1992) and along the eastern margin of the Indian Ocean through to the Arabian Gulf (Bishop 2003). It is found on the continental shelf, usually over muddy bottoms during the day, rising to the surface

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at night, often in large schools, swimming on their sides (Carpenter et al. 1997). It is of commercial interest not only in Kuwait but also throughout the Arabian Gulf. Annual catches of black pomfret from Kuwait have decreased from 290 tons in 1995 to 50 tons in 2003, and increased to 122 tons in 2004. The average annual catch is 150 tons. Black pomfret contributes about 3.1% to Kuwait's annual total fish catches (Ministry of Planning 2005).

Information on any aspect of the biology of this commercially important fish from the Arabian Gulf region is scarce (Dadzie 2007; Dadzie et al. 2007). Limited information is also available from Indian waters (Sivaprakasam 1965; Rao 1973; Pati 1983). In view of the continued importance of black pomfret to the commercial fishery in Kuwait, coupled with the scarcity of information on its biology both locally and regionally, the present study on aspects of its reproductive biology was undertaken, specifically to investigate the: (i) seasonal fluctuations in the gonadosomatic index (GSI), (ii) relationship between maturation pattern and temperature, (iii) maturity stages, (iv) seasonal distribution of maturity stages (v) size at maturity, (vi) sex ratio and (vii) fecundity.

Materials and Methods

Fresh samples of black pomfret were collected from commercial gillnet catches in the northern part of the Kuwaiti waters of the Arabian Gulf (Fig. 1), during a 24-month sampling period, from October 2003 to September 2005.

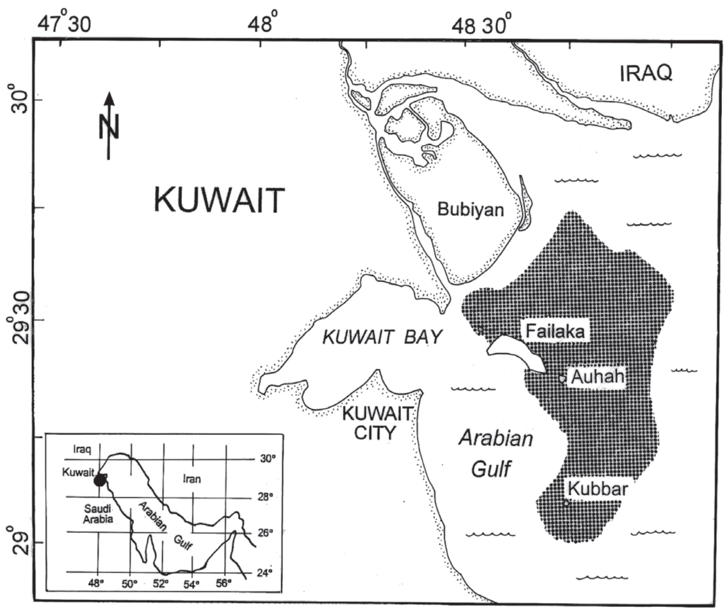

Figure 1. Map of Kuwait showing the study area (hatched)

The nets used were 1000-2500 m in length, with a stretched mesh size of 13.8 cm. They were set 2-5 km offshore at depths ranging from 7 to 15 m. They were set at dawn between 03:00 and 05:00 h, and raised for the collection of the fishes between 13:00 and 14:00 h. The vessels with black pomfret catches docked by 15:30 h, and study samples were obtained within 2 h and kept on ice.

The total length (cm), standard length (cm) and body weight (g) of each fish were recorded upon arrival in the laboratory. All the sampled fish were then dissected and their ovaries removed, weighed (to the nearest 0.001g) and fixed in Bouin's fixative for a minimum of 48 h. Large ovaries were cut into pieces before fixing to allow maximum penetration of the fixative. They were then dehydrated in alcohol, cleared in toluene and infiltrated with and embedded in paraffin wax. Sections of 5 µm were stained in hematoxylin and counterstained with eosin for studies of the histological changes and maturity stages during the annual reproductive cycle and also to confirm the stages delineated by macroscopic characteristics.

The gonadosomatic index (GSI) was calculated using the formula: GSI = Gonad weight/Ovary-free body weight x 100. The frequencies of the various maturity stages and the monthly variations in the GSI were used to study the maturation pattern and the extent of the breeding season. Mean monthly temperature values of the Kuwaiti waters covering the period of the study, obtained from the Kuwait Environmental Authority, were used to investigate the possible effects of temperature on the reproductive pattern of black pomfret in Kuwaiti waters. The size at maximum reproductive capacity, when 50% of the fish were mature (L_{50}), was investigated separately for each sex and pooled data for the two years were fitted to a logistic curve using SPSS 12.0. The ratio of females to males in monthly samples was determined separately for each year and the results tested statistically (χ^2 test of homogeneity).

Mature ovaries, dissected from females during the spawning season (February to August), were used for fecundity studies. They were fixed for several weeks in Gilson's fluid, teased apart and vigorously shaken from time to time to separate the eggs. Total fecundity, defined as the standing crop of advanced yolked oocytes in the ovary (Hunter et al. 1992) was estimated for 107 fish by the gravimetric method (Kipling & Frost 1969), based on five 1-g sub-samples. Relative fecundity, defined as fecundity divided by female weight (Hunter et al. 1992), was also determined. The relationships of total fecundity to ovary-free body weight, fish standard length, and ovary weight and egg size were determined by regression analysis. Data on relative fecundity were regressed on fish standard length and ovary-free body weight to determine the relationships of these two parameters to relative fecundity.

Results

Seasonal fluctuations in the gonadosomatic index

The GSI profiles for males and females during the two study cycles (October 2003 - September 2004 and October 2004 – September 2005) were remarkably similar. Briefly, after a quiescent period from October to January, characterized by low GSI values, mean GSI values appeared to increase from February reaching a peak in June 2004 (Fig. 2a) and in March 2005 (Fig. 2b) for males.

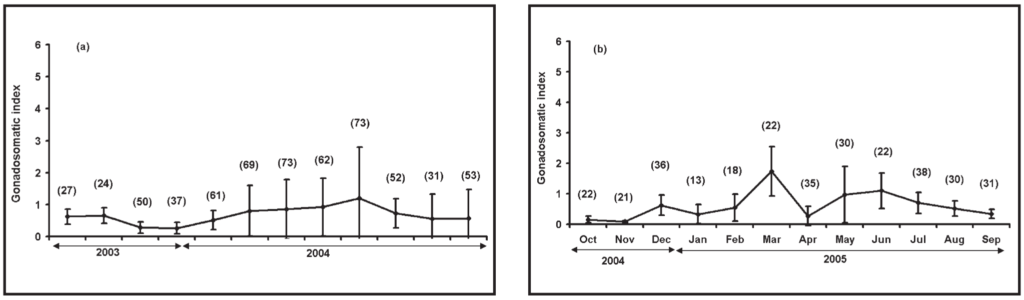

Figure 2. Seasonal fluctuations in gonadosomatic indices in male *P. niger*: (a) from October 2003 to September 2004, (b) from October 2004 to September 2005. Figures in parentheses indicate sample size

In the females, a minor peak was observed in March in both years and a major one in June and July 2005 (Fig. 3a and b), before declining from September.

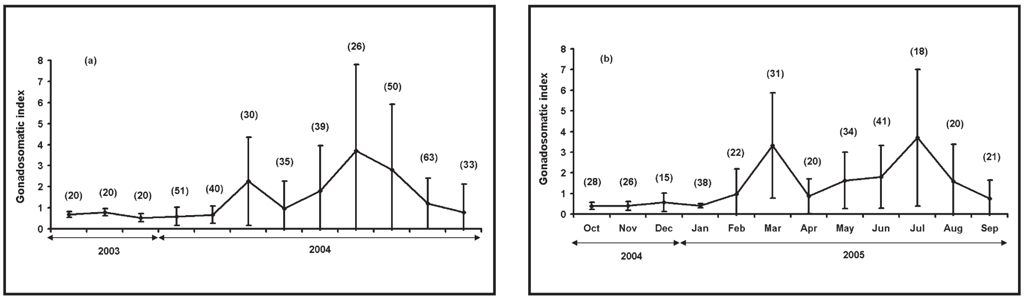

Figure 3. Seasonal fluctuations in gonadosomatic indices in female *P. niger*: (a) from October 2003 to September 2004, (b) from October 2004 to September 2005. Figures in parentheses indicate sample size.

Relationship between maturation pattern and temperature

The maturation pattern, investigated through the analyses of the seasonal changes in GSI, was correlated with fluctuations in water temperature values during the study period. Two distinct phases in water temperature fluctuations were observed in Kuwaiti waters during both the first and second cycles - a reduction from October 2003 to January/ February, and an increase from January/February to September (Fig. 4a and b).

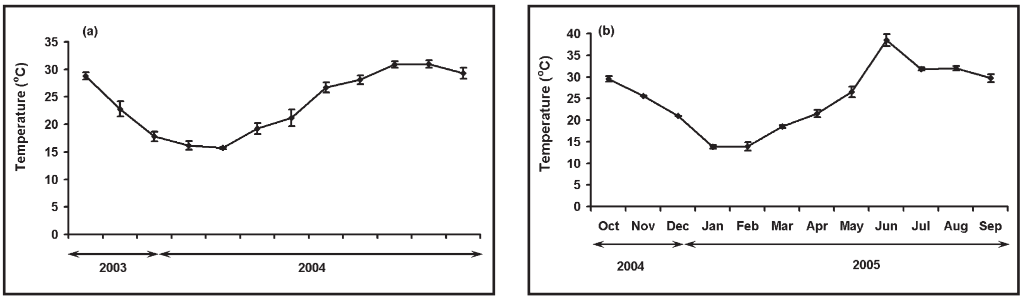

Figure 4. Monthly temperature values from Kuwaiti waters: (a) from October 2003 to September 2004, (b) from October 2004 to September 2005

Pooled data for the two years indicated very strong positive correlations between temperature values and GSI from the pre-spawning month (January) to the early months of spawning (February/March) ($r=0.835$, $p<0.05$ for males and $r=0.764$, $p<0.05$ for females).

Maturity stages

Based on morphological and histological characteristics, six maturity stages were identified in male (table 1) and seven in female (table 2) black pomfret.

Seasonal distribution of maturity stages

From October to January of both years, males and females in Stage I (immature), Stage II (developing) and Stage III (maturing) dominated the samples (Figs 5a and 6a).

This period coincided with the phase of reducing water temperatures depicted in Fig. 4. From February to September also of both years, the samples were dominated by

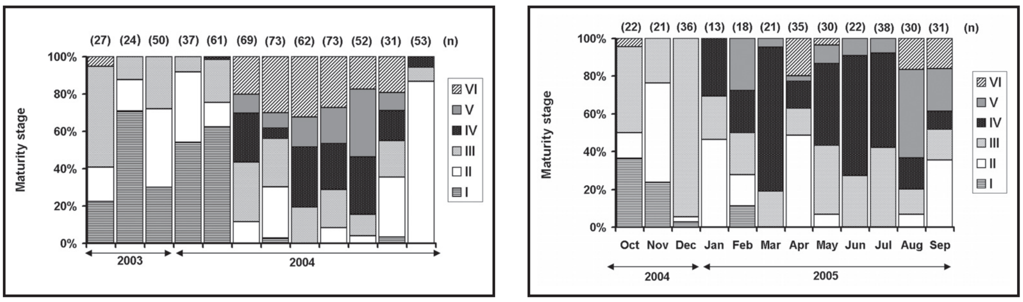

Figure 5. Seasonal distribution of maturity stages in male *P. niger*: (a) from October 2003 to September 2004, (b) from October 2004 to September 2005. Figures in parentheses indicate sample size.

Table 1. Macroscopic and histological characteristics of the maturity stages of male *P. niger*

	Maturity stage	Macroscopic description	Histological description
I)	Immature virgin/ Recovering spent	Testis in the form of two tiny transparent threads, occupying about 29% of the peritoneal cavity. Sex determination with unaided eye impossible.	Presence of primary germ cells (PGC), spermatogonia (SG) of subsequent generations, primary spermatocytes (PS) and secondary spermatocytes (SS).
II)	Developing virgin /Recovering spent	Testis increases in size up to about 53% of the peritoneal cavity and takes on a light-brownish hue.	Presence of lobules filled with PGC and SG with increasing number of PS and SS. Few cysts containing spermatids (ST) also appear.
III)	Maturing	Testis further increases in size, becomes dirty-white and occupies about 58% of the body cavity.	Increasing numbers of cell types, especially PS, SS, numerous ST as well as those recruiting into spermatozoa (SZ) confined within roundish or elongated lobules.
IV)	Mature	Testis enlarged, turgid and whitish, occupying about 69% of the body cavity.	Lobules containing SZ increase in size as a result of formation of large numbers of SZ. However, interlobular spaces containing intermediate cell types still present.
V)	Ripe/Running	Testis fully developed, highly vascularized, creamy-white in colour and occupies about 74% of the peritoneal cavity. Milt runs freely with a slight pressure on the peritoneum.	Both the roundish and elongated lobules are now packed with SZ. Very little evidence of interlobular spaces containing intermediate cell types.
VI)	Spent	Both partially and fully shrunken testes present, occupying about 59% of body cavity.	Some SZ present in partially shrunken testis, but empty spaces characterize fully shrunken testis.

Table 2. Macroscopic and histological characteristics of the maturity stages of female *P. niger*

Maturity stage		Macroscopic description	Histological description
I)	Immature virgin/ Recovering spent	Ovary small, thread-like and of equal length. It is translucent in immature virgins and reddish in recovering spents due to strong vascularization. It occupies about 39% of the body cavity.	Spaced ovigerous folds oriented towards the centre of the ovary containing oogonia (OG) and early perinucleolar stage oocytes (EPO) present.
II)	Developing	Ovary increases in size, pale-yellow to dark pink in colour and occupies about 50% of the peritoneal cavity.	Ovary filled with EPO and late perinucleolar stage oocytes (LPO).
III)	Developed/ Maturing	Ovary increases rapidly in size, yellowish, and occupy about 58% of the body cavity. Sex differentiation easily discernible.	Primary vitellogenic stage oocytes containing lipid vesicles in the cytoplasm appear in the ovary, indicating beginning of vitellogenesis.
IV)	Maturing	Large ovaries containing yellow oocytes, occupying 69% of body cavity. Eggs are visible through the thin ovary wall.	Rapid increase in quantities of lipid vesicles. Appearance of secondary vitellogenic stage oocytes containing yolk granules. The latter and the lipid vesicles increase rapidly in size forming yolk globules and oil droplets.
V)	Mature	Ovary swollen, maximally distended and yellowish, occupying 80% of body cavity. Eggs clearly visible throughout the thin ovary wall. A network of blood vessels surrounds the organ.	Presence of tertiary vitellogenic oocytes in which both yolk globules and oil droplets have increased considerably in size, and the latter coalescing.
VI)	Spawning	Ovary very large, yellowish-red in colour, occupying about 94% of the body cavity, with an increased vascularization. Eggs freely extrude upon slight application of pressure on the peritoneum.	Numerous migratory-nuclear oocytes and hydrated oocytes are present in the ovary.
VII)	Spent	Ovary reddish and flaccid, occupying about 66% of the body cavity. In totally spent females, it is shrunken, but in partially spent ones eggs meant for subsequent spawning(s) are present.	Ovary of totally spent females contain numerous post-ovulatory follicles at different stages of degeneration, atretic oocytes and a reserve stock of oogonia and perinucleolar stage oocytes; ovary of partially spent female contain, additionally, oocytes in different vitellogenic stages.

Stage IV (mature males and maturing females), Stage V (ripe/running males and mature females), and Stage VI (spent females) fish (Figs 5b and 6b). This period coincided with rising water temperature phase in Kuwait.

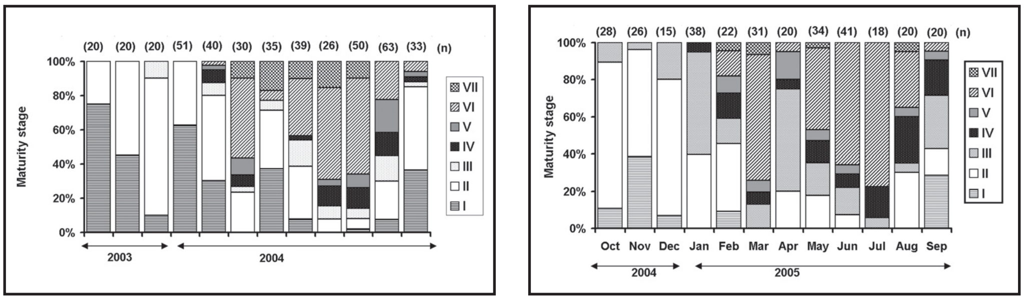

Figure 6. Seasonal distribution of maturity stages in female *P. niger*: (a) from October 2003 to September 2004, (b) from October 2004 to September 2005. Figures in parentheses indicate sample size

Size at maturity

Maturing testis (Stage III and above) and maturing ovaries (Stage III and above) were considered mature for the determination of minimum size at sexual maturity. Pooled data covering the two-year study period indicated that males mature slightly earlier than females. Size at maturity ranged from 15 to 32 cm SL in males and 20 to 42 cm SL in females. In length groups larger than 17.5 cm SL over 50% of the males were mature (Fig. 7a); in length groups greater than 29 cm SL over 50% of the females were mature (Fig. 7b).

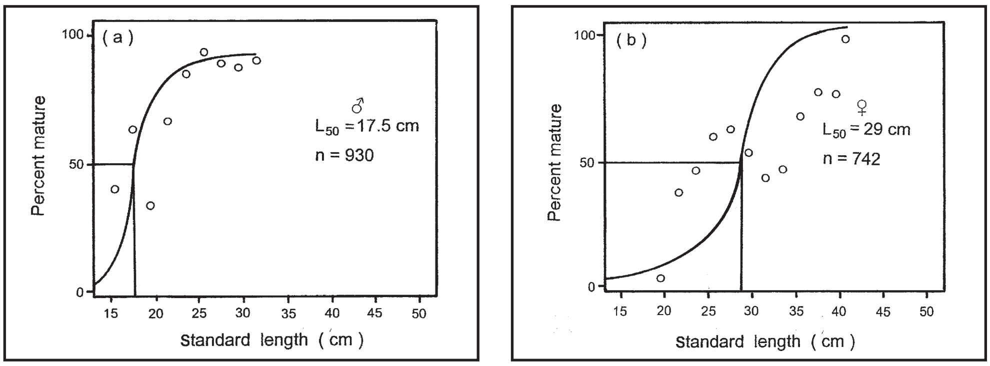

Figure 7. Logistic curve for determining size at sexual maturity in *P. niger*

The smallest mature males in the sampled population belonged to the 16.5-18.4 cm length class and only 5.6% of them were mature. The females started maturing at a length class of 18.5-20.4 cm, and only 3.1% of them were mature. The logistic function revealed that the minimum size at sexual maturity (L_{50}) was attained at a size of 30.9 cm SL in males (r^2 = 0.284) and 36.5 cm SL in females (r^2 = 0.355).

Sex ratio

Out of 1 036 specimens sampled during the first year of the study, 612 were males and 424 were females, giving an overall sex ratio of 1.4:1 which did not deviate significantly from the hypothetical distribution of 1:1 ($\div^2$ = 61.9; d.f. = 11; $p<0.05$). During the second year, 627 specimens were sampled, out of which 315 were males and 312 were females, giving an overall sex ratio of 1.02:1, which also did not deviate significantly from the hypothetical 1:1 ($\div^2$ = 46.9; d.f. = 11; $p<0.05$).

Fecundity

Total fecundity (TF) based on 107 mature females varied widely even among fishes of the same size. It ranged from 71 305 (for a 39.8 cm SL female weighing 1 572.5 g) to 3 895 449 (for a 49 cm SL female weighing 2 630 g), with a mean of 1 216 734 eggs. At 95% confidence limits, linear relationships were found between fecundity and: (a) ovary-free body weight ($p<0.05$; r^2 =57.5%), (b) standard length ($p<0.05$; r^2= 59.2%), and (c) ovary weight ($p<0.05$; r^2=70.8%). The r^2 values revealed that the relationships were strong, the strongest being that between fecundity and ovary weight. In contrast, fecundity and egg size revealed a negative correlation ($p>0.05$; r^2 0.9%). Relative fecundity (RF) was 948 eggs/g ovary-free body weight, and did not reveal any significant relationship with either standard length (p=0.023; r^2 =4.9%) or ovary-free body weight (p=0.439; r^2 =0.6%).

Discussion

Information on the maturation pattern and spawning of black pomfret in the Arabian Gulf does not exist. Within the region, however, reports are sparse and disparate and are all from Indian waters. Sivaprakasam (1965) observed mature fish from April till November, but ripe fish were recorded only in September, while actual spawners were found in September and October in Saurashtra waters. In view of the occurrence of spent fish in August, the author concluded that spawning had already started in July. These observations are different from the two-month spawning duration (February and March) reported from the Godovary Estuary (Rao 1973). In the Bay of Bengal, the species spawns from March to June (Pati 1983). Contrary to all the above reports, the present study has revealed that black pomfret has an extended spawning periodicity in the Arabian Gulf, beginning in February and ending in September. The evidence for this was derived from the presence of both males and females in the ripe/running condition (Stage V) in the samples from February till September. After a quiescent period from October till January, the increase in the GSI in both sexes from February, till their decline in September, yields further evidence in support of this claim. In the only sympatric species studied from the Kuwaiti waters, *Pampus argenteus*, Dadzie et al. (1998, 2000) reported spawning from April to August although ripe males were encountered until September, while Almatar et al. (2004) observed spawning from mid-May to early October.

For the enhancement of gametogenesis leading to maturity and spawning, the role of temperature has been recognized (Ahsan 1966; de Vlaming 1974; Asahina & Hanyu 1983; Summers 1996). In the present study, the spawning season of black pomfret in Kuwait coincided with the period of increased sea temperatures. Furthermore, the strong positive correlation observed between the annual variations in GSI and sea temperature confirms that temperature, either alone or in combination with other unknown factors, triggers spawning in the species, similar to the observations found in *Acanthopagrus latus* in Kuwaiti waters (Abou-Seedo et al. 2003).

The determination of minimum size at sexual maturity based on pooled data for the two years revealed that minimum maturity in black pomfret from Kuwait is attained at a larger size in females than in males, similar to reports from Indian waters (Sivaprakasam 1965; Pati 1983). The ratio of males to females in monthly samples, which did not depart significantly from the hypothetical 1:1, confirms the observations also from the Indian representatives of the species (Sivaprakasam 1965; Pati 1983).

Fecundity in fishes characteristically varies considerably among individuals of the same size and age (Mathur & Ramsey 1974; Emery & Brown 1978; Dadzie et al. 2000, 2003), similar to the results observed in the present study. At the interspecific level, this may be due to intra-seasonal changes in the rhythm of egg laying as some fish may have shed many successions of eggs, some only a few, and others not at all (Mathur & Ramsey 1974; Emery & Brown 1978). This is especially characteristic of batch spawners (Yamamoto & Yamazaki 1961; Watson et al. 1992), the category to which black pomfret belongs.

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An Appraisal of Trawl Fishery of Kerala

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Abstract

Trawl fishery of Kerala contributes about 35-50% of the annual landings of the state. The ever increasing international demand for shrimps and cuttlefishes further induced acute competition, higher investment and continuous up gradation of trawlers. The technical specifications, capital investment, catch composition and revenue for single and multiday units has drastic differences. The present study aims to highlight the trawl landings of Kerala state and comparative efficiency of these units operating at Cochin Fisheries Harbour. The data was systematically collected during 2005-2006 in a pre-designed schedule covering all seasons. The secondary data was obtained from various publications of State Fisheries Department and CMFRI. The craft and gear specifications of these units indicate the increasing trend of capital intensity in an already overcapitalized sector. The study indicates that the shift towards multi-day units will further increase due to better catch and returns. Although the multi-day trawlers are economically efficient, the wastes and discards generated from these units are not advisable for the long-term sustainable development of our open access marine fisheries. Regulations in terms of number of units, unit operations or quota system for trawlers appear to be imminent for the efficient management of marine fishery resources of the state.

Introduction

In India, trawling on commercial level was commenced at Cochin during early sixties and was later spread to other parts of the country (Kuriyan, 1965). During late seventies and early eighties, a conspicuous change in the trawlers took place. The major development brought about were change in materials for construction, hull form, marine engines, propulsion system and optimization of energy. Some shrimp trawlers were exclusively operated during night hours. These boats, popularly known as night boats subsequently extended their operations to the day as fish trawl and this cooperation continues for multiple days. By the mid eighties, most of the bigger boats switched over to this type of stay –over fishing to bring quality fishes. This method of fishing resulted in substantial increase in returns mainly by saving the fuel cost. Moreover, these 'night

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boats' were continuously expanding the trawling grounds and venturing into deeper areas. In recent years, multi-day trawl fishery has expanded considerably and now it exists as a separate fishery. The ever-increasing international demand for shrimps and cephalopods further induce acute competition, higher investment and continuous demand for up gradation of trawlers. The technical specifications, capital investment, catch composition and revenue for single and multi-day day units differs drastically. Keeping an eye on of the duality and rapid technological changes happening in trawl fishery, a comprehensive study with particular emphasis on economic efficiency was done in this study.

Database and methods

The data was systematically collected during 2005-2006 in a pre-designed schedule covering all seasons. The secondary data was obtained from various publications of State Fisheries Department and Central Marine Fisheries Research Institute (CMFRI). The regular costs and earnings data collected during the data collection were utilized for the calculation of the economic indicators such as net profit, rate of return etc. The various components of costs are classified into operating costs and fixed costs. The operating costs include all those costs, which are incurred only when the vessels are under operation and fixed costs are those incurred even if there is no operation. Data on catch (Kg) and efforts were collected on weekly observation of trawl landings. Analysis of economic performance of different types of fishing units was assessed using indicators like net operating income, Capital productivity and labour productivity.

Results and Discussion

A successful trawl design is evolved after many trials and errors in design and field trials. The design of a trawl gear depends on the length of the vessel, horsepower of installed engine, type of fishery to be exploited and fish behaviour. The effective towing power of engine is an important aspect in selection of gear design. A particular design may be a combination of standard designs of related size class of vessel with the same engine horsepower. Specifications of crafts deployed for trawling in Kerala is given in Table:-1.

Both single day and multi day trawlers are in operation in Kerala. The single day trawlers are very old and made of wood. The life of this type of boat is only upto 20 years.They don't have fish hold. Instead ice is used for preserving fish and their efficiency is very low. The depth of trawling ranges from 60-420m.The duration of voyage in single day trawlers is restricted to 7 hours.

Table 1. Specifications of crafts deployed for trawling

Description	Single day boats	Multi day boats
Overall Length (OAL)	9-11.5m	11-17.1m
Breadth	3-4m	3.5-5.0m
Gross tonnage	9-20	15-40
Draught	1.4-1.7	1.6-2.0
Type of construction	Carvel planking with FRP up to deck level	Carvel planking with FRP up to deck level
Materials used	Wood	Wood,steel
Horse Power	35-75	80-160
Fish-hold capacity	Nil	3-15tonnes
Number of crew	4	5-12
Endurance	Single day	Upto 9 days
Navigational and other equipments	Echosounder,Magnetic Compus,GPS,wireless, Mobile	Echosounder, SONAR, Magnetic Compus, GPS, wireless, Mobile, TV, DVD
Life of boat	Upto20years	Upto20years

In Sakthikulangara region, when the fish catch is low they go for chunk fishing at night. Another avocation for them is the Babilonia fishing at night. This gives them very good price in the tune of Rs. 45-60 / Kg for live specimens. The multi day trawlers are made up of steel and they have all modern amenities. The depth of operation ranges from 80-420 m. Some trawlers resort to less than five-day trips. But new boats are going for more than five-day trips, as they are more fuel-efficient.

With the increase in size of vessels, the dimension of the gear also has to be changed for getting maximum efficiency. The trawlers presently operating off Cochin area are resource specific as two main types of trawl nets –for shrimps and fishes are in use. The trend of using different types of gear started in late 1980's.They take both fish net and shrimp net while going for fishing. Some boats in addition to fish and shrimp net also take some other type of nets to catch cephalopods also. Table 2 depicts the specifications of commonly used gears by trawl fleets.

Table 2. Specifications of the gears used by trawl fleets.

Description	Single day boats	Multi day boats	
Type of net	Shrimp net, fish net	Shrimp net	fish net
Length of head rope (m)	27	31	33-37
Length of foot rope (m)	31	35	38-41
Mesh size (mm)			
Body	25-30	10-20	30-38
Cod end	15-18	35-40	22-24
Net material	Nylon	Nylon	Nylon
Thickness (mm)	0.5-0.75	1.0-1.25	2.0-2.5
Otter board:			
Shape	Flat rectangular	Flat rectangular&V shaped	
Weight(kg)	100-130	170-190	
Warp material	16mm synthetic rope	10-12mm wire rope	

Catch composition of trawlers of different combinations

The major species composition in the annual catch of the mechanized trawler varied from centre to centre. In Neendakara, the deep-sea prawns dominated with 64% followed by cuttlefish (11%), whereas in Munambam, the major species landed was the less priced threadfin breams (31%) followed by high priced cuttlefish (24%). Some quantity of ribbon fishes (12%) also was landed here. Prawns contributed only 5% to the total catch. Ribbonfishes were the major contributor in the mechanised trawler at Cochin Fisheries Harbour (60%) followed by cuttlefish (17%).

Economic evaluation

The annual average costs and earnings of various fishing units operating from the selected landing centres were worked out. Along the Kerala cost, sharing of the gross revenue after deducting fuel cost in operational cost is the prevailing system of payment of wages for fishing labour. In the case of trawlers, the labour share is 35%. The other operational costs include auction charges, batas and cost towards repair and maintenance of the craft and gear. In Kerala, the share of workers remains unchanged for the last many years and there has been no attempt on the part of wage earners in fishing industry to get their share increased. This may be because the workers get higher wages each year due to the increase in revenue. This increase in revenue is mainly due to the continuing increase in fish prices in recent years.

The fixed cost includes the interest for initial investment, its depreciation and insurance. Depreciation is the permanent and continuing decline in the value of capital asset, which in the case of mechanized fishing units comprised of hull, engine, gear and other accessories. The depreciation for hull and engine, together constituted the craft, was about 10% of its capital investment assuming a life span of 10 years. The depreciation for the gear used in the mechanized trawler was about 50% assuming a maximum life span of two years.

Economic Performance of both single day and multi day trawlers on trip basis and annual basis was worked out and shown in Table 3 and 4 respectively.

Table 3. Economic Performance of trawlers (Average/trip)

Particulars	Single day trawl	Multi-day Trawl
Catch (Kg)	157	1541
Gross revenue (Rs)	10,121	61,186
Labour (Rs)	3390	10246
Fuel (Rs)	3493	28940
Auction (Rs)	674	3204
Others(Rs)	1203	4441
Operating cost (Rs)	8760	46831
Net operating income (Rs)	1361	14355
Capital productivity ratio	0.86	0.76
Labour productivity (Kg/trip)	39	193

The per trip analysis showed that in single day trawlers 40% of operating cost is spent for fuel and 39% for labour. Though the average gross revenue works out to be Rs. 10121/- the average net operating income works out to be Rs. 1360/ where as in multi day trips 62% of operating cost is for fuel and 22% for labour. Higher operating cost is due to more days spent on voyage, where most of the trawlers went for 9-10 days voyage. Here net operating income per trip is Rs. 14355/- as their gross revenue is more. The major reason for this increased production and revenue is that these crafts are equipped with fish finding devices which help them to locate the more valuable species such as cuttlefish and squids and these crafts have high storage capacity. One very important issue in the case of multi day trawlers is that they are not paying any attention to low value fishes though they are equally efficient in nutritional point of view. If they can give some attention in this regard their returns can be increased. This aspect has to be carefully addressed as these discards are creating some environment issue also. As the low value and juveniles are discarded or thrown out after catching, mortality rate is very high. In countries like India where protein deficiency is a major nutritional issue this type of crime cannot be tolerated. According to Sathiadhas (1998), community participation in fisheries management should be introduced by creating awareness among fishermen and encouraging ‘co-operative fishing’ instead of ‘competitive fishing’.

The annual profit from the trawlers having Overall Length (OAL) of 9-11.5m and going for single day trips was Rs. 20,24,200/- and the trawlers having Overall Length (OAL) of 11-17.1m and going for multi day trips was Rs. 36,71,160/- (Table 4).

Table 4: Annual Economic Performance of trawlers

Particulars	Single day trawl	Multi-day Trawl
Catch (Kg)	31,400	92,460
Gross revenue (Rs)	20,24,200	36,71,160
Labour (Rs)	6,78,000	6,14,760
Fuel (Rs)	6,98,600	17,36,400
Auction (Rs)	1,34,800	1,92,240
Others(Rs)	2,40,600	2,66,460
Operating cost (Rs)	17,52,000	28,09,860
Net operating income(Rs)	2,72,200	8,61,300
Capital productivity	0.86	0.76
Labour productivity	2530	6798

The single day trawlers operating along the Kerala coast operated with an annual average operating cost of Rs. 17,52,000 (Table 4). The annual catch of these units was 31,400kg generating annual gross revenue of Rs. 20,24,200. Capital productivity (operating ratio) was also worked out to compare the economic efficiency of the trawlers. Capital productivity is defined as the portion of gross revenue that would cover the operating expenses. The operating ratio works out to 0.86, indicating that 86 per cent of gross revenue generated is used to cover its operating expenses. The higher operating cost due to the higher fuel and auction charges can be attributed to the higher value of the operating ratio. Major components of operating expenses are fuel (40 percent) and crew wages (39 per cent).

The annual average operating cost of multi day fishing unit operating in Kerla was Rs. 28,09,860.Almost 84 percent of the operating expenses is incurred on fuel and wages. The annual catch of these units was 92460 Kg generating annual gross revenue of Rs. 36,71,160. The operating ratio works out to 0.76, indicating that 76 per cent of gross revenue generated is used to cover its operating expenses.

The capital productivity indicators show that the multi day trawlers are more efficient (0.76) compared to single day trawlers operating in Kerala (0.86). Labour productivity is the average quantity of product generated per labourer. Labour productivity for single day trawlers is worked out to be 39 Kg/ labourer whereas in multiday trawlers it was 193Kg/labourer. Hence multiday trawlers are found to be more efficient.

Conclusion

Fishery resources are continuously exploited using fishing vessels whose number, size and effectiveness are always increasing. Marine fishing is capital intensive mainly due to the increased tempo of mechanization as well as motorization of non-mechanized units. According to Panikkar et al. (1991) fishing along our inshore waters is transforming from a subsistence level to a cash crop operation and now the fishermen are very much conscious about their profit margin. The craft and gear specifications of these units indicate the increasing trend of capital intensity in an already overcapitalized sector. The study indicates that the shift towards multi-day units will further increase due to better catch and returns.

Although the multi-day trawlers are economically efficient, the wastes and discards generated from these units are not advisable for the long-term sustainable development of our open access marine fisheries. The major areas to be focused are effort regulation, by-catch exclusion or reduction, use of selective and eco-friendly fishing gear, and bio-socio-economic considerations in management where the coastal communities are involved for preservation of biodiversity and integration of inshore fishing activities with coastal management plans. Regulations in terms of number of units, unit operations or quota system for trawlers appear to be imminent for the efficient management of marine fishery resources of the state.

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