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Fish Production and Energy Requirement during Demersal and Aimed Midwater Trawling by Intermediate Range Freezer Trawler

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Abstract

This paper deals with the fish production and relative energy consumption in demersal and midwater trawling based on data derived from cruises of Intermediate range freezer trawler that operated in Indian waters during 1993-94. The trawler has length overall of 62.2 m, gross registered tonnage of 1898 and installed engine power of 2400 hp. Operations were conducted between 14° and 22° N lat., off west cost of India, within a depth range of 31 and 125 m, using 47.5 m four-seam bottom trawl rigged with bobbin gear and 70.0 m mid-water trawl. The present investigations have shown that significant improvements in landings were obtained during aimed midwater trawling, off west coast of India. The mean daily landings rose from an average of 5.66 t, during bottom trawling to 22.84 t, during midwater trawling, realising over 300% improvement in the landings that manifested in a significant reduction in the consumption of fuel per unit volume of fish landed by midwater trawling. Overall fuel consumption per kg fish landed by bottom trawling and midwater trawling worked to be 1.34 and 0.33 kg, showing a four-fold difference. The difference in daily fuel expenditure per unit volume of fish between bottom and aimed mid-water trawling was found to be highly significant statistically. As there is intense concentration of effort in the bottom trawl fisheries, it could be advantageous from the resource management perspective and also from the energy conservation point of view, to encourage diversification to midwater trawling, in a controlled manner without compromising on sustainability of resources. Stern trawler does not require any large-scale modifications in structure or deck layout, for undertaking midwater trawling. However, the vessel must be large enough, highly manoeuvrable and sufficiently powered to tow a large mouthed midwater trawl at speeds exceeding 4.5 knots; should be equipped with acoustic fish detection (sonar and echosounder) and trawl monitoring systems; and in addition, must have provision for handling and preserving large volume landings.

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Introduction

With the declaration of the Exclusive Economic Zone in 1986 over 2 million square kilometres extending to 200 nautical miles from coastline was brought under the exclusive national jurisdiction. This has restricted the free and open access of the distant water fishing fleet operated by developed nations such as Japan, Taiwan, Korea and erstwhile USSR, in Indian EEZ. The need for developing deep sea fishing industry for harvesting the extended area of jurisdiction was reflected in the formulation of deep sea policy during 1991 and subsequent reviews, in India (Anon 1977; Anon1996; Vijayakumaran & Haridas 1998).

Over 180 fishing vessels of 20 m L_{OA} and above and about 30 large vessels under joint venture / charter scheme were in operation in Indian waters in 1990s. The vessels under joint venture / chartered category were large trawlers equipped for undertaking demersal and/or midwater trawling, and long liners. The main objective of the deep sea fishing policy was modernisation of deep sea fishing sector of India, in a phased manner by acquisition of technology and expertise in order to harvest the under-utilised deep sea fishery resources in the Indian EEZ.

Single boat midwater trawling was developed in the late 1940s to capture pelagic shoaling fishes. Since then, the development and application has progressed at a great speed in different parts of the world. In midwater trawling, the gear must easily be manoeuvrable in accordance with the distribution of shoals of target species between surface and seabed. Successful midwater trawling require effective use of acoustic fish detection and net monitoring equipment, in order to guide the net accurately into the position of shoals. Both one-boat and two-boat midwater trawling are practised in commercial fisheries, in different parts of the world (Amos 1980; Brandt 1984; Sainsbury 1996).

Pelagic species are generally fast swimming. They form dense shoals during daytime and respond to stimuli collectively. Pelagic fishes posses well developed sight and hearing capabilities. Midwater trawling is most successful when shoals are dense and large; when fishes are less active due to low ambient temperature or physiological states such as nonfeeding, spawning or spent conditions; and when visibility is poor causing fish to react more slowly. Main design requirements for midwater trawls are high stability, large mouth opening, low turbulence and low drag. Midwater trawls require largest possible opening of the mouth, permitted by the available towing force of the vessel at the required towing speed, allowing roughly 30% margin of reserve power for gear manoeuvre during operations. The large mouth opening is usually achieved by the incorporation of large side panels. Wings are consequently reduced in size or absent altogether in the midwater trawl, unlike the bottom trawl. The mouth opening may be oval, circular or square depending on the design and rigging. In some designs of surface operated trawls, the lower panel is extended ahead of the head rope.

This is to counteract the tendency of pelagic fishes to dive downwards in response to disturbance caused by the approaching trawl (Scharfe 1969; Kristjonsson 1971; Amos 1980; Anon 1993).

Smooth water flow through the net is extremely important requirement in midwater trawls in order to prevent turbulence in the proximity of the trawl mouth. In order to achieve smooth water flow, midwater trawls are longer and more finely tapered with longer extension piece and codend, compared to bottom trawls. In addition, very large meshes are generally used in the wing and front trawl sections, which reduce the drag and improve the water flow. Most pelagic fishes are effectively herded into the small meshed hind part and codend by the large meshes used in the front trawl sections. Increase in mesh sizes of the front trawl sections is a major design improvement that has taken place in midwater trawl design. Mesh size of 200 mm used in earlier designs gradually increased to 3000 mm or more in large modern midwater trawls. Pelagic trawls wherein front sections are replaced with large meshes and ropes are technologically superior, in terms of drag reduction and increase in volume filtered (Brabant et al.1980). Fishes are generally subject to herding effect when they approach near the netting panel (Glass et al. 1993). Effective dimension of the net mouth thus, would be less by the distance from the panel at which the herding response is effective.

One of the important features of midwater trawl is the high towing speed required for catching fast-swimming pelagic fish. Size of the net and the resultant drag has to be matched with the vessel's available towing force at the towing speed effective for the target species. Drag of midwater trawl is primarily determined by twine surface area of the netting. Drag is also influenced by the shape and taper of the net and gear appurtenances such as floats, weights and sheer devices. Drag changes significantly with changes in towing speed (Reid 1977; Brandt 1984). The most popular otter board used for one-boat mid-water trawling is Suberkrub design (Suberkrub 1959). Suberkrub otter boards have high hydrodynamic efficiency with a sheer-drag ratio in excess of 6.0, high aspect ratio of 2:1, and is vertically cambered. Introduction of Suberkrub otter boards is a significant development in one-boat midwater trawling (Brandt 1971; FAO 1974).

Some of the earliest developmental stages in one-boat midwater trawling were the introduction of Larsson's phantom trawl; British Colombian trawl for herring; and Cobb pelagic trawl for Pacific hake (McNeely 1965; Brandt 1971; Anon 1993). Wider commercial acceptance of the technique took place after the successful introduction of the German one-boat midwater trawling system in 1960s and the simultaneous developments in the acoustic fish detection and net monitoring equipment. Success of the German one-boat trawling has proved that a midwater trawl of large mouth area towed even at a slower speed could be more effective than a trawl with small mouth area towed at a greater speed (Scharfe 1969). Midwater trawl designs operated in different parts of the world tend to be similar in general features with regional variations in the structure and rigging of the gear components.

In aimed midwater trawling, the vessel is steamed towards the shoal of the target species after its location by sonar. At a reasonable distance from the target shoal, the gear is shot and its position under water is adjusted so as to take in the shoal. The fishing depth of the trawl is adjusted by varying vessel's speed and the length of the towing warps, either singly or in combination, for quicker response. The net monitor (net sonde) attached to the head rope of the trawl provides the data on the fishing depth, vertical opening of the net mouth and the catch entering the net, which are required for successful gear manoeuvre, based on data from sonar and echosounder. Additional sensors in net monitoring system could provide data on the horizontal spread of the trawl mouth and at otter boards, *in-situ* temperature and catch increment in the codend (Larsen 1989; Mross 1989; Allison 1971; Horn 1971).

In midwater trawl, towing tension is on the head rope and the vertical opening is primarily achieved by the depressor weights attached to the lower wing-ends. Floats attached to the head rope help in keeping the head rope clear during shooting and hauling operations. Thus, in midwater trawling, the combined length of the lower sweeps and bridles between wing-end and otter board are longer than the upper sweeps and bridles. In contrast, the towing tension is on the ground rope along the seabed in the bottom trawl and the vertical opening is achieved by lifting the head rope from the seabed by net design features and floatation. Towing speed varies with the target species. A towing speed of 2.5 -3.0 knots may be good enough for slow swimming target species while for fast swimming species towing speeds of 4.5 - 8.0 knots are used.

In India, a few studies have been conducted on midwater trawling from small trawlers (Perumal 1966; Sivan et al. 1979; Kartha & Sadanandan 1973; Mhalathkar et al. 1975; Mhalathkar et al. 1983). Indo-Norwegian Project conducted two-boat midwater trawling using midwater trawls of 17.6 m head rope from 9.76 m L_{OA} vessels, within 25 m depth zone off Kerala coast, during 1973-78. Single-boat midwater trawling was conducted off Kerala within 40 m depth, using 26.8 m x 26.8 m midwater trawl from 17 m L_{OA} (233 hp) and 19.81m L_{OA} (220 hp) vessel; 43.3m x 43.3 m midwater trawl from 23.8 m (480 hp) vessels and 36.1 m x 44.4 m midwater trawl from 28.0 m L_{OA} (400 hp) vessel, during 1973-75. Major landings during these operations were silver bellies, glass perches, clupieds, carangids and anchovies (Verghese 1975; Verghese & Nair 1975; Oommen 1989). Midwater trawling trials were conducted from *FORV Sagar Sampada* using three variations 46.4 m midwater trawls, rigged with 750 kg Lindholmen pelagic otter boards (Kuttappan et al. 1989). Midwater rope trawls were operated successfully during Indo-Polish Industrial Fisheries Survey, along the north-west coast of India for pelagic resources such as horse mackerel, ribbonfish, elasmobranchs, pomfret, catfishes and carangids (Dwivedi et al. 1977). Investigations on midwater trawling for Antarctic Krill, were conducted during the First Indian Antarctic Krill Expedition 1995-'96 (FIKEX) (Boopendranath et al. 1999).

The relative operational energy consumption in fish production by demersal and aimed midwater trawling has not been studied so far in Indian waters. The objectives of the present study were (i) survey of the fishing gear, equipment and operation in an intermediate range freezer trawler operations; (ii) determination of daily production of the trawler by midwater and bottom trawling in the north-west coast of India; and (iii) estimation of fuel consumption and energy requirement per unit production of fish by aimed midwater trawling and bottom trawling.

Materials and Methods

Data on landings obtained during two cruises of Intermediate Range Freezer Trawler, which operated in Indian waters during 1993-94 were utilised for this study. The freezer trawler was designed for stern trawling using a bottom or midwater trawl and for onboard production of frozen fish packed in master cartons; production of fish meal and technical fish oil from nonfood fish; for storage of fish products and transportation of products to the port or transhipment to the transport ships (reefer vessels). The trawler had a length overall of 62.2 m and gross registered tonnage of 1898 t. It had an installed engine horsepower of 2400 hp, controllable pitch propeller in the steering nozzle and stern ramp for lowering and lifting of the fishing gear. Details of the vessel, equipment and fishing operations were collected during a cruise onboard in January 1994. The main particulars of the vessel, power plant and fishing equipment are given in Table 1.

Operations were conducted off west coast of India, between latitudes 14° and 22° N, within the depth range of 31 and 125 m (Fig. 1). Bottom trawl of 47.5 m headline length rigged with bobbin gear for rough bottom operation and oval otter boards were used for bottom trawling. Midwater trawl of 70.0 m headline length and suberkrub otter boards were used for aimed midwater trawling. Design details of bottom trawl and midwater trawl are given in Fig. 2 and 3, respectively. Vertical opening of the trawl mouth and horizontal opening between otter boards were measured by acoustic trawl monitoring equipment with sensor for vertical opening attached to the trawl headline and otter boards. Towing speed was measured using Doppler log.

Table 1. Main particulars of the Intermediate Range Freezer Trawler, engine and equipment

Vessel Details		
Length overall	:	62.2 m
Beam	:	13.8 m
Light draught	:	4.19 m
Load draught	:	5.21
GRT	:	1898 t
NRT	:	492 t
Sea autonomy under fuel reserve	:	34 days
Crew	:	35 men
Main Engines		
Type	:	Diesel 8VD 26/20 AL-2
Number of engines	:	2
Power	:	1200 hp (880 kW) at 1000 rpm
Specific fuel consumption per engine	:	166 $kg.hp.h^{-1}$
Auxiliary engine		
Number of engines	:	2
Power	:	846 hp (622 kW)
Specific fuel consumption	:	162 $g.hp.h^{-1}$
Emergency engine		
Number of engines	:	1
Power	:	102 hp (74 kW)
Specific fuel consumption	:	178 $g.hp.h^{-1}$
Fish Finding Devices		
Fish finder	:	1 no.; 19.7 kHz; range: 3000 m
Search light sonar	:	1 no.; 19.7 kHz; range 1500 m
Trawl monitoring system	:	1 no.; 25.5 kHz
Fishing Equipment		
Fishing gear		
Bottom trawl with appurtenances	:	2 nos
Midwater trawl with appurtenances	:	4 nos.
Otterboards- oval slotted type	:	6.5 m^2; 1750 kg each -1 set
Otterboards- suberkrub type	:	8.0 m^2; 2750 kg each - 2 sets

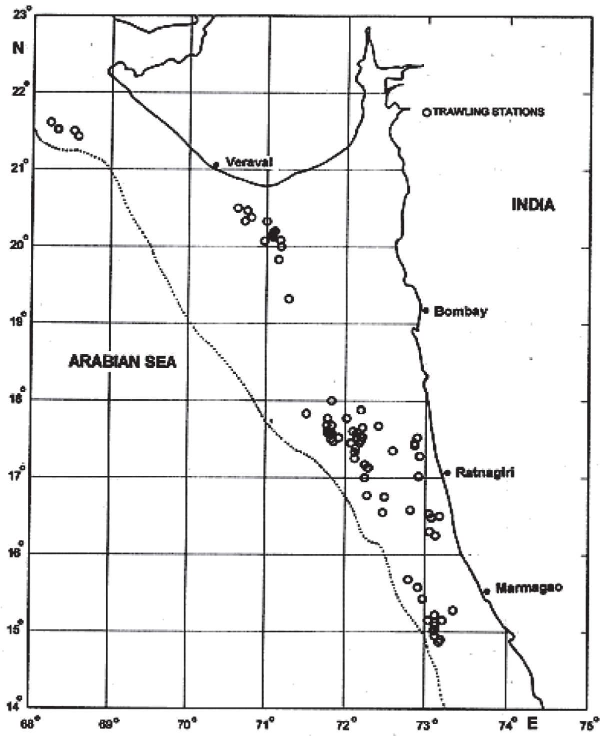

Figure1. Trawling stations of intermediate range Freezer Trawler

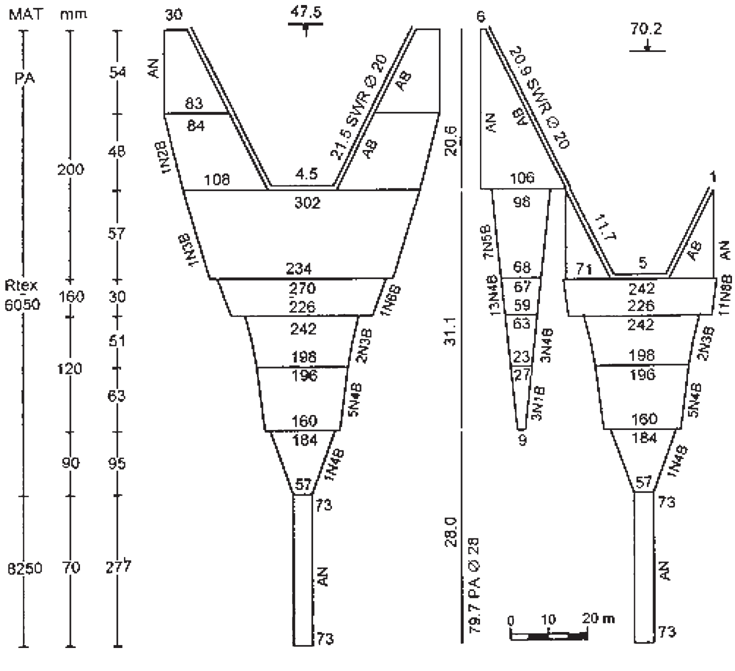

Figure 2. Design of 47.5 m bottom trawl.

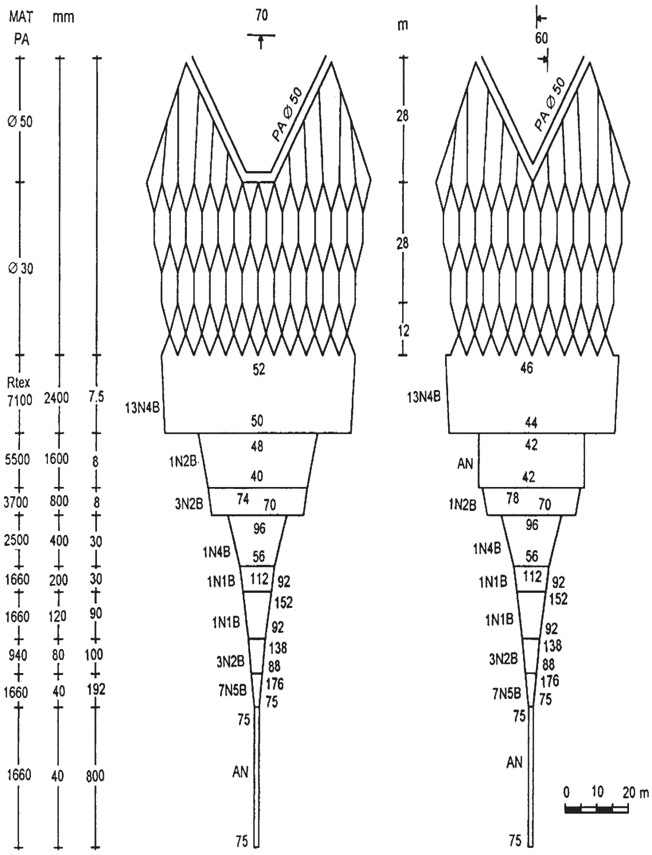

Figure 3. Design of 70.0 m midwater trawl

Average duration of tow for bottom trawling was 2.57 h and 2 to 4 hauls were taken in day. The mean towing speed was 4.23±0.24 knots. Seventy-five hauls spread over 24 days were taken during the period of study. Average duration of tow for aimed midwater trawling was 1.88 h and 2 to 3 hauls were taken per day. The mean towing speed was 4.33±0.16 knots. Seventeen aimed midwater trawling operations spread over 6 days, were conducted during the period of study. Details of operation and catch for bottom and aimed midwater trawling are given in Tables 2 and 3 respectively.

Table 2. Operational and catch details of the Intermediate Range Freezer Trawler

	Bottom trawling	Aimed midwater trawling
No of days	24	6
No of hauls	75	17
Depth range, m	50-121	31-125
Mean duration of hauls, h	2.57	1.88
Total catch, kg	135732	137051
Mean catch.day^{-1}, kg	5655.5	22841.8
SE of catch .day^{-1}	1461.9	7620.7

Table 3. Composition of landings by bottom trawling and aimed midwater trawling

Catch components	Catch (Kg)
Bottom trawling	
Pseudoscianids	1299
Pomfrets	2079
Squids & Cuttlefish	3156
Indian Mackerel	5265
Catfish	7402
Sciaenids	7798
Horse Mackerel	11610
Ribbon Fish	17604
Nemipterids	18369
Perches	34993
Miscellaneous	26157
Sub-total	135732
Aimed midwater trawling	
Scad	400
Horse Mackerel	135955
Miscellaneous	696
Sub-total	137051
Grand total	272783

Estimated duration of time spent for searching, shooting, towing and hauling for both bottom and aimed midwater trawling operations are given in Fig 4.

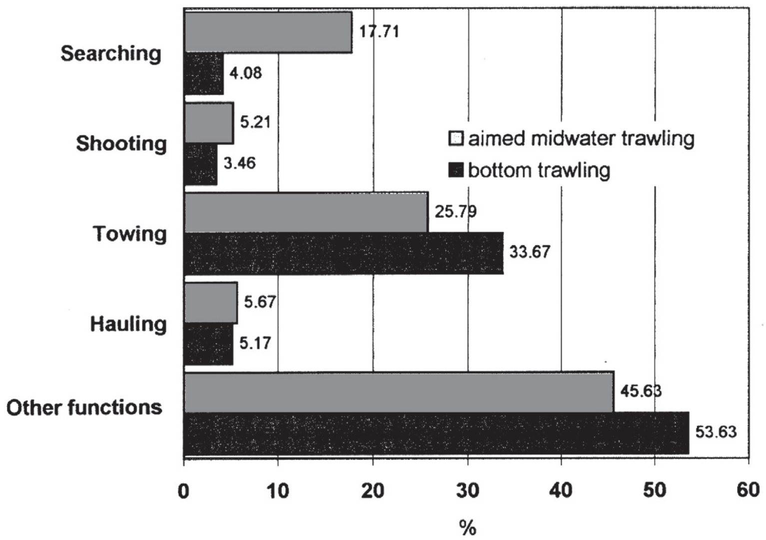

Figure 4. Time utilisation per day of Intermediate Range Freezer Trawler

Fuel consumption was estimated from the specific fuel consumption of the power plant for the estimated period of operation of the engines. Fuel consumption per unit volume of fish landed by both bottom trawling and aimed midwater trawling were determined from the data on the daily fuel consumption and landings. The daily fuel consumption per kg of fish landed were subjected to statistical analysis using Student *t*-test after logarithmic transformation of data, to determine if there is any significant difference between the values obtained for bottom trawling and aimed midwater trawling.

Results and Discussions

Total landings during the period of operations were 272.8 t, of which 135.7 t were landed during 24 days by bottom trawling and 137.1 t by aimed midwater trawling during 6 days of operations. Mean daily catch for bottom and aimed midwater trawling were, respectively, 5655.5 kg (SE: 1461.9) and 22841.8 kg (SE: 7620.7) (Table 2). Vertical opening of the bottom trawl was determined to be 6 m and horizontal opening between otter boards was 85 m. Midwater trawl attained a vertical opening of 45 m and horizontal opening between the otter boards was 160 m. Wing-end spread of midwater trawl was estimated to be 42 m.

Perches constituted 25.78 % of the total landings by demersal trawling followed by nemipterids (13.53 %), ribbonfish (12.97 %), horse mackerel (8.55 %), sciaenids (5.75 %), cat fish (5.45 %), Indian mackerel (3.88 %), squids and cuttlefish (2.33 %), pomfrets (1.53 %), pseudosciaenids (0.96%) and miscellaneous fishes (19.27%). Over 99 % of the landings by aimed midwater trawling was constituted by horse mackerel (*Megalaspis cordyla*) (Fig. 5). Scad (*Decapterus* sp.) and miscellaneous species contributed 0.29 % and 0.51 %, respectively (Table 3).

Figure 5. A catch of 22 tonnes of horse mackerel (*Megalaspis cordyla*), obtained during aimed midwater trawling, off west coast of India

Fuel consumption pattern for bottom trawling and midwater trawling, during the period of observations is given in Table 4. Total fuel consumed during the period of observations was 227.10 t of which 181.68 t was consumed during bottom trawling and 45.42 t during midwater trawling. Results of statistical analysis of the daily variation in the values of fuel consumption per kg of fish landed by bottom trawling and aimed midwater trawling are given in Table 5.

Table 4. Fuel consumption per unit volume of fish caught by bottom trawling and aimed midwater trawling

	Bottom trawling	Aimed midwater trawling
Total catch, kg	135732	137051
Fuel consumption, kg	181680	45420
Overall fuel consumption (kg fuel.kg fish^{-1})	1.339	0.331

Table 5. Results of Student *t*-test of the variation in fuel consumption per unit volume of fish landed between bottom trawling and aimed midwater trawling, using log transformed data.

	Bottom trawling	Aimed midwater trawling
Mean	0.437	-0.231
Variance	0.293	0.389
Pooled variance	0.310	
Observations	24	6
df	28	
t - stat	2.626 (Significant at 0.01 level)	

The catch data showed large scale variations in the volume of total catch and catch composition. During bottom trawling operations, the vessel spent on an average 3.46 % of the 24 h period for shooting, 33.67 % for towing, 5.17 % for hauling, 4.08 % for ground shifting and 53.63 % for fishing-independent functions. During aimed midwater trawling operations, the vessel spent on average 5.21 % for shooting, 25.79 % for towing, 5.67 % for hauling, 17.71 % for acoustic search for schools using search light sonar and 45.63 % for other functions unrelated to fishing (Fig. 4).

Average fuel consumption was estimated to be 7.75 t.day^{-1}. Overall fuel consumption per kg fish landed by bottom trawling and midwater trawling worked to be 1.339 and 0.331 kg, showing a four-fold difference (Table 4). Daily values of fuel consumption per kg of fish landed ranged from a maximum of 37.83 kg to a minimum of 0.33 kg, with a mean value of 5.46 kg (SE: 1.61) and a median value of 2.70 kg, for bottom trawling. For midwater trawling, daily values of fuel consumption per kg of fish landed ranged from a maximum of 5.36 kg to a minimum of 0.15 kg, with a mean value of 1.44 kg (SE: 0.85) and a median value of 0.32. Statistical analysis of the values of daily fuel consumption per unit volume of landed catch, has shown that the variation between the two types of operations is highly significant ($p < 0.01$; df: 28) (Table 5). There is about four-fold increase in the consumption of fuel used for unit volume of landings by bottom trawling compared to aimed midwater trawling operations.

Investigations on one-boat midwater trawling off the south-west coast by Integrated Fisheries Project, during 1973-85, from five large trawlers of 17.0-28.0 m L_{OA} (220-480 hp), have given encouraging results (Oommen, 1989). The overall catch rate realised was 102.8 kg.h^{-1}. The landings consisted of anchovies 22.3 %, followed by glass perch (18.3 %), carangids (11.8 %), sardines (11.6 %), silver bellies (8.6 %), mackerel (0.5 %) and other fishes (26.9 %). Results of midwater trawling using rope trawl from *M.T. Muraena*, during Indo-Polish Industrial Survey, have shown that there is distinct possibility of catching sizeable quantity of horse mackerel, ribbon fish, pomfrets, catfish and carangids by midwater trawling from about 70-120 m along north-west coast of India (Anon 1979). Taking advantage of the diurnal migration, squid and cuttlefish can also be caught by midwater trawling (Joseph 1985).

Conclusions

The present investigations have shown that significant improvements in landings were obtained during aimed midwater trawling, off west coast of India. The mean daily landings rose from an average of 5.66 t, during bottom trawling to 22.84 t, during midwater trawling, realising over 300 % improvement in the landings, which manifested in a significant reduction in the consumption of fuel per unit volume of fish landed by midwater trawling. As there is intense concentration of effort in the bottom trawl fisheries, it could be advantageous from the resource management perspective and also from the energy conservation point of view, to encourage diversification to midwater trawling, in a controlled manner without compromising on sustainability of resources. Stern trawler does not require any large-scale modifications in structure or deck layout, for undertaking midwater trawling. However, the vessel must be large enough, highly manoeuvrable and sufficiently powered to tow a large mouthed midwater trawl at speeds exceeding 4.5 knots; should be equipped with acoustic fish detection (sonar) and trawl monitoring systems (net monitor or net sonde); and, in addition, must have provision for handling and preserving high volume landings.

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