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RESEARCH ARTICLE

ASSEMBLAGES OF MACROBENTHOS WITH TRANSPLANTED OYSTERS IN MULKY ESTUARY, WEST COAST OF INDIA

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ABSTRACT

Studies on transplantation of oysters in Mulky estuary was carried out from January 2010 to May 2010. The assemblages of macrobenthos with the transplanted oyster were recorded. The assemblages of macrobenthos increased gradually over the months. Overall, the population density and species of macrobenthos with transplanted oysters varied from 36 to 86No/m². Minimum number of macrobenthos was recorded during February 2010 and maximum during April and May 2010. The survival rate of transplanted oysters varied between 86.60 and 100%. The environmental factors such as the water temperature, sediment temperature, salinity, DO, pH, sedimentation rate, phytoplankton wet weight and sediment organic carbon varied from 29.89 to 34.45°C, 31.60 to 35.20ºC, 24.20 to 33.62ppt, 4.69 to 4.85mg/l, 7.18 to 7.8, 0.28 to 1.33g/m²/month, 8.86 to 58.47 mg/m³ and 0.02 to 0.24% respectively.

INTRODUCTION

Oysters are found worldwide in the coastal waters of temperate, subtropics and tropics (Grabowski *et al*., 2008). They generally inhabit in lagoons, estuaries and backwaters. They are sedentary with pelagic larval stages. They are ecosystem engineers influence on many ecological processes such as maintenance of biodiversity, population and food web dynamics, nutrient cycling and water quality maintenance (Alexandra *et al*., 2010). They are considered as the keystone species that provide habitat, shelter and food for their associates and are excellent tools for biodiversity restoration in degrading brackishwater ecosystems (Sanjeevaraj, 2008). Intertidal oyster beds provide habitat for many infaunal and epifaunal species (Hosack *et al*., 2007). Over 300 species have been identified as depending, either directly or indirectly on intertidal oysters (Al-Khayat and Al-Ansi, 2008). Oyster beds provide shelter, food or spawning substrate for many species of macrobenthos (Harding and Mann, 2001). The greater abundance of bottom feeding fish over oyster bed can be related to the greater abundance of macrobenthos (John and Megan, 2005). Lower species diversity and lower number of individuals of macrobenthos in oyster bed are indicative of the stressful environmental conditions (Feldman *et al*., 2000). Therefore, inventory of the macrobenthos with oyster beds are important for community based ecological approach to understand the additional factors affecting the oyster population such as disease, competition and predation (Tolley and Volety, 2005).

Oysters have long been transplanted in new waters to support commercial cultivation or to establish a wild fishery (Newell, 2004, Newell *et al*., 2005). Oysters have been introduced worldwide to 73 countries (Jennifer *et al*., 2005). In many parts of the world, introduced oysters compose a majority of oyster harvests (Cerco and Noel, 2007).

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Introductions of oysters in new waters or transplantation from oyster beds to non-oyster bed areas of the same water can greatly enhance oyster population abundance and production, as well as populations of associated native species (Jennifer *et al*., 2005). Therefore, it may be important to transplant oysters in new waters or in the non-oyster bed area of the same water to support commercial cultivation or to establish a wild fishery and also for restoration of degraded environment. In the present study, assemblage pattern of macrobenthos with transplanted oysters was studied to understand the overall well being of the transplanted oysters in non-oyster bed areas of the same estuary.

MATERIALS AND METHODS

Study area

The Mulky estuary (Lat. 13º 05¹ N and Long. 74º 46¹ E) is located about 29 km north of Mangalore (13° 4N' 74° 17' E), Karnataka, India was selected as the study area for the present investigation. The estuary has an average depth of 3 m and the tidal range is about 1 m. The bottom of the estuary is mostly a mixture of silt and sand. This is a typical tropical estuary which experiences wide variations in salinity. During the south-west monsoon period (June to September), the estuary is flooded with fresh water influx from the land and the estuarine waters become almost fresh. During this period, the water is turbid throughout the estuary. During the non-monsoon period, estuarine water comprises mainly of sea water as the freshwater influx is very much reduced.

Determination of survival rate of transplanted oysters and assemblage of macrobenthos

This study has been carried out from January 2010 to May 2010. Thirty oysters (*S. cucullata*) were transplanted from oyster bed 1 (OB1) to non-oyster bed 1A (NOB1A), non-oyster bed 1B (NOB1B) and non-oyster bed 1C (NOB1C) experimental cages (Plate 1). Similarly, thirty oysters (*S. cucullata*) were transplanted from oyster bed 2 (OB2) to non-oyster bed 2A (NOB2A), non-oyster bed 2B (NOB2B) and non-oyster bed 2C (NOB2C) experimental cages (Plate 2). The survival rate of transplanted oysters at each experimental cage was recorded and expressed in percentage. The population density of macrobenthos associated with transplanted oysters in all the experimental cages were recorded and expressed in No/m².

NOB 1A NOB 1B NOB 1C

Plate 1. Experimental cages at NOB 1A, NOB 1B and NOB 1C at OB1 in Mulky estuary

NOB 2A NOB 2B NOB 2C

Plate 2. Experimental cages at NOB 2A, NOB 2B and NOB 2C at OB2 in Mulky estuary

Determination of environmental factors

The water quality parameters such as water temperature, sediment temperature, salinity, DO, pH and sediment organic carbon (SOC) were recorded according to the standard methods. Besides, sedimentation rate (SR) and phytoplankton wet weight (PWW) were also estimated.

RESULTS

The survival rate of oysters transplanted from OB1 to NOB 1A, NOB 1B and NOB 1C from January 2010 to May 2010 in Mulky estuary is given in the Table 1 and Fig.1. At the station NOB1A, no mortality was observed during January and February 2010. During March and April 2010, the survival rate was 96.66%. The minimum survival rate 93.33% was recorded during May 2010. At NOB 1B station, no mortality was recorded during the period of experiment. At NOB 1C station, 100% survival rate was observed during January 2010 and February 2010. During March and April 2010, the observed survival rate was 90%. The minimum survival rate 86.6% was recorded during May 2010. The survival rate of oysters transplanted from OB 2 to NOB 2A, NOB 2B and NOB 2C from January 2010 to May 2010 in the Mulky estuary is given in the Table 2 and represented graphically in the Fig.2. During January 2010 no mortality of transplanted oyster was observed in NOB 2A, NOB 2B and NOB 2C. At NOB 2A, during February 2010 also no mortality was recorded. The minimum survival rate 90% was recorded at NOB 2B during May 2010. At NOB 2A and NOB 2 C stations, recorded survival rate was 93.33% during March 2010 to May 2010. The population density of macrobenthos at NOB1A, NOB1B and NOB1C is given in the Fig.3. At NOB 1A, the density of macrobenthos varied from 43 to 81 No/ m². The maximum density of macrobenthos was recorded during May 2010 and minimum during February 2010. At NOB 1B, the density of macrobenthos varied from 39 to 78 No/ m². The maximum density of macrobenthos was recorded during May 2010 and minimum during February 2010. At NOB 1C, the density of macrobenthos varied from 48 to 86 No/ m². The maximum density of macrobenthos was recorded during May 2010 and minimum during February 2010. The population density of macrobenthos at NOB2A, NOB2B and NOB2C is given in the Fig.4. At NOB 2A, the density of macrobenthos varied from 36 to 46 No/ m². The maximum density of macrobenthos was recorded during May 2010 and minimum during February 2010. At NOB 2B, the density of macrobenthos varied from 39 to 60 No/ m². The maximum density of macrobenthos was recorded during February 2010 and minimum during April 2010. At NOB 2C, the density of macrobenthos varied from 46 to 77 No/ m². The maximum density of macrobenthos was recorded during May 2010 and minimum during March 2010.

DISCUSSION

The oysters were transplanted from the oyster beds to non-oyster beds of Mulky estuary to study the survival rate of transplanted oysters and assemblage of macrobenthos with transplanted oysters. The survival rate of transplanted oysters varied between 86.60 and 100%. These results clearly indicate that transplanted oysters showed good survival rate in the non- oyster bed areas. At non-oyster bed areas, the environmental factors such as the water temperature, sediment temperature, salinity, DO, pH, sedimentation rate, phytoplankton wet weight and sediment organic carbon varied from 29.89 to 34.45ºC, 31.60 to 35.20ºC, 24.20 to 33.62ppt, .69 to 4.85mg/l, 7.18 to 7.8, 0.28 to 1.33g/m²/month, 8.86 to 58.47 mg/m³ and 0.02 to 0.24% respectively. Thus, above mentioned environmental factors may be conducive for the growth of the transplanted oysters.

Table 1. Monthly distribution of water temperature, sediment temperature, salinity, dissolved oxygen, pH, sedimentation rate, phytoplankton wet weight, sediment organic carbon and macrobenthos at NOB 1A from January 2010 to May 2010

Sl. No.	Parameters	Jan		Feb		Mar		Apr		May	
1.	Water temperature(°C)	31.20		30.36		32.10		32.56		33.32	
2.	Sediment temperature(°C)	32.11		32.54		34.22		33.90		34.66	
3.	Salinity(‰)	24.63		28.97		29.48		31.20		33.21	
4.	Dissolved oxygen(mg/l)	4.46		4.68		3.99		3.86		3.68	
5.	pH	7.43		7.52		7.66		7.75		7.57	
6.	Sedimentation Rate (g/m²/month)	0.29		0.86		0.95		1.22		1.27	
7.	Phytoplankton wet weight (mg/m³)	26.36		64.84		30.26		14.48		17.30	
8.	Sediment organic carbon (%)	0.17		0.15		0.12		0.02		0.04	
9.	Associated fauna(No/m²)	Sp*	D*	Sp	D	Sp	D	Sp	D	Sp	D
		C. obstusa	12	*C. obstusa*	24	*C. obstusa*	26	*C. obstusa*	32	*C. obstusa*	23
		C. citrinum	7	*C. citrinum*	16	*C. citrinum*	22	*C. citrinum*	20	*C. citrinum*	18
		Fiddler crab	2	*Natica tigrina*	2	*Natica tigrina*	6	*Natica tigrina*	5	Fiddler crab	7
				Fiddler crab	1	Fiddler crab	6	Barnacle	4	*Natica tigrina*	9
						Barnacle	4	Hermit crab	2	Barnacle	8
								Fiddler crab	5	Blue crab	4
								Oyster drill	1	Diopatra	2
										Fiddler crab	8
										Polychaetes	2
	Total		21		43		64		69		81

Sp*: Species D*: Density

Table 2. Monthly distribution of water temperature, sediment temperature, salinity, dissolved oxygen, pH, sedimentation rate, phytoplankton wet weight, sediment organic carbon and macrobenthos at NOB 1B from January 2010 to May 2010

Sl. No.	Parameters	Jan		Feb		Mar		Apr		May	
1.	Water temperature(°C)	31.82		31.10		32.68		33.23		34.45	
2.	Sediment temperature(°C)	32.32		31.99		34.56		34.38		34.85	
3.	Salinity(‰)	24.20		29.10		30.20		31.42		33.00	
4.	Dissolved oxygen(mg/l)	4.68		4.20		4.44		3..94		4.12	
5.	pH	7..53		7..57		7.70		7.68		7.42	
6.	Sedimentation Rate(g/month)	0..51		0.46		0.84		0.87		1.16	
7.	Phytoplankton wet weight(mg/m³)	26.33		47.32		28.69		23.47		14.77	
8.	Sediment organic carbon (%)	0.11		0.13		0.10		0.08		0.12	
9.	Associated fauna(No/m²)	Sp	D	Sp	D	Sp	D	Sp	D	Sp	D
		C. obstusa	12	*C. obstusa*	14	*C. obstusa*	28	*C. obstusa*	23	*C. obstusa*	34
		C. citrinum	5	*C. citrinum*	18	*C. citrinum*	20	*C. citrinum*	16	*C. citrinum*	26
				Natica tigrina	5	*Natica tigrina*	3	*Natica tigrina*	3	Fiddler crab	2
				Fiddler crab	2	Fiddler crab	2	Hermit crab	2	*Natica tigrina*	8
								Diopatra	1	Barnacle	1
								Blue crab	2	Hermit crab	2
										Blue crab	3
										Polychaetes	2
	Total		17		39		53		47		78

Table 3. Monthly distribution of water temperature, sediment temperature, salinity, dissolved oxygen, pH, sedimentation rate, phytoplankton wet weight, sediment organic carbon and macrobenthos at NOB 1C from January 2010 to May 2010

Sl. No.	Parameters	Jan		Feb		Mar		Apr		May	
1.	Water temperature(°C)	32.20		31.70		33.00		32.85		34.52	
2.	Sediment temperature(°C)	33.15		32.13		33.98		35.00		34.76	
3.	Salinity(‰)	24.52		29.00		30.64		32.27		33.24	
4.	Dissolved oxygen(mg/l)	4.39		4.55		4.82		4.30		3.86	
5.	pH	7.44		7.29		7.49		7.52		7.27	
6.	Sedimentation Rate(g/month)	0.47		0.98		1.05		1.25		1.32	
7.	Phytoplankton wet weight(mg/m³)	24.73		58.47		32.20		20.38		15.55	
8.	Sediment organic carbon (%)	0.18		0.15		0.04		0.13		0.07	
9.	Associated fauna(No/m²)	Sp	D	Sp	D	Sp	D	Sp	D	Sp	D
		C. obstusa	9	*C. obstusa*	16	*C. obstusa*	32	*C. obstusa*	34	*C. obstusa*	36
		C. citrinum	4	*C. citrinum*	24	*C. citrinum*	28	*C. citrinum*	26	*C. citrinum*	28
				Natica tigrina	4	*Natica tigrina*	6	*Natica tigrina*	8	Fiddler crab	9
				Fiddler crab	4	Fiddler crab	3	Hermit crab	2	Barnacle	7
						Blue crab	2	Blue crab	3	*Alpeus sp*	1
								Barnacle	4	Hermit crab	2
								Oyster drill	1	Blue crab	3
		Total	13		48		71		78		86

Table 4. Survival rate (%) of oysters transplanted from OB 1 to NOB 1A, NOB 1B and NOB 1C from January 2010 to May 2010 in Mulky estuary

Months	NOB 1A	NOB 1B	NOB 1C
	Survival rate (%)	Survival rate (%)	Survival rate (%)
January 2010	100	100	100
February 2010	100	100	100
March 2010	96.66	100	90
April 2010	96.66	100	90
May 2010	93.33	100	86.66

Table 5. Monthly distribution of water temperature, sediment temperature, salinity, dissolved oxygen, pH, sedimentation rate, phytoplankton wet weight, sediment organic carbon and macrobenthos at NOB 2A from January 2010 to May 2010

Sl. No.	Parameters	Jan		Feb		Mar		Apr		May	
1.	Water temperature(°C)	30.56		31.68		31.85		33.20		34.47	
2.	Sediment temperature(°C)	31.60		31.54		32.29		33.86		35.20	
3.	Salinity(‰)	25.57		30.33		31.83		32.05		32.94	
4.	Dissolved oxygen(mg/l)	3.86		4.36		4.69		3.88		4.42	
5.	pH	7.18		7.52		7.67		7.59		7.73	
6.	Sedimentation Rate(g/month)	0.28		0.64		0.87		0.80		1.20	
7.	Phytoplankton wet weight(mg/m³)	41.36		56.39		27.35		12.97		20.26	
8.	Sediment organic carbon (%)	0.21		0.34		0.06		0.02		0.4	
9.	Associated fauna(No/m²)	Sp	D	Sp	D	Sp	D	Sp	D	Sp	D
		C. obstusa	8	*C. obstusa*	14	*C. obstusa*	23	*C. obstusa*	20	*C. obstusa*	15
		C. citrinum	6	*C. citrinum*	19	*C. citrinum*	13	*C. citrinum*	14	*C. citrinum*	23
				Natica tigrina	2	Fiddler crab	3	*Natica tigrina*	3	Fiddler crab	2
				Fiddler crab	1			Barnacle	3	Barnacle	3
								Blue crab	4	Blue crab	2
										Alpeus sp	1
	Total		14		36		39		44		46

Table 6. Monthly distribution of water temperature, sediment temperature, salinity, dissolved oxygen, pH, sedimentation rate, phytoplankton wet weight, sediment organic carbon and macrobenthos at NOB 2B from January 2010 to May 2010

Sl. No.	Parameters	Jan		Feb		Mar		Apr		May	
1.	Water temperature(°C)	29.89		32.45		32.34		33.80		34.79	
2.	Sediment temperature(°C)	31.87		33.65		32.80		34.58		35.10	
3.	Salinity(‰)	25.80		29.97		32.25		32.42		33.36	
4.	Dissolved oxygen(mg/l)	4.48		4.85		4.47		4.22		3.69	
5.	pH	7.21		7.58		7.46		7.38		7.80	
6.	Sedimentation Rate(g/month)	0.42		0.29		0.94		1.07		1.33	
7.	Phytoplankton wet weight(mg/m³)	26.49		38.48		30.23		25.38		21.99	
8.	Sediment organic carbon (%)	0.16		0.19		0.13		0.04		0.07	
9.	Associated fauna(No/m²)	Sp	D	Sp	D	Sp	D	Sp	D	Sp	D
		C. obstusa	14	*C. obstusa*	24	*C. obstusa*	16	*C. obstusa*	9	*C. obstusa*	19
		C. citrinum	6	C. citrinum	29	*C. citrinum*	21	*C. citrinum*	14	*C. citrinum*	11
		Natica tigrina	2	*Natica tigrina*	3	*Natica tigrina*	2	*Natica tigrina*	3	Fiddler crab	2
				Fiddler crab	4	Barnacle	2	Barnacle	1	Barnacle	3
								Polychaetes	2	Oyster drill	2
								Barnacles	2	Hemit crab	1
										Diopatra	2
	Total		22		60		41		31		40

Table 7. Monthly distribution of water temperature, sediment temperature, salinity, dissolved oxygen, pH, sedimentation rate, phytoplankton wet weight, and sediment organic carbon and macrobenthos at NOB 2C from January 2010 to May 2010

Sl. No.	Parameters	Jan		Feb		Mar		Apr		May	
1.	Water temperature(°C)	32.46		32.87		33.00		34.32		35.12	
2.	Sediment temperature(°C)	32.30		33.99		33.42		34.89		34.89	
3.	Salinity(‰)	26.23		31.33		32.68		32.95		33.62	
4.	Dissolved oxygen(mg/l)	4.65		4.64		4.07		3.87		4.48	
5.	pH	7.36		7.47		7.66		7.53		7.59	
6.	Sedimentation Rate(g/month)	0.30		0.59		0.74		0.92		1.28	
7.	Phytoplankton wet weight(mg/ m³)	33.42		42.10		27.98		18.48		21.40	
8.	Sediment organic carbon (%)	0.21		0.15		0.24		0.13		0.08	
9.	Associated fauna(No/m²)	Sp	D	Sp	D	Sp	D	Sp	D	Sp	D
		C. obstusa	16	*C. obstusa*	24	*C. obstusa*	16	*C. obstusa*	17	*C. obstusa*	26
		C. citrinum	9	*C. citrinum*	29	*C. citrinum*	13	*C. citrinum*	28	*C. citrinum*	24
				Natica tigrina	3	*Natica tigrina*	9	*Natica tigrina*	12	Fiddler crab	8
				Fiddler crab	2	Fiddler crab	4	Barnacle	2	*Natica tigrina*	6
						Barnacle	4	Fiddler crab	2	Barnacle	6
								Hermit crab	2	Hermit crab	4
								Oyster drill	1	Blue crab	3
	Total		25		58		46		64		77

Table 8. Survival rate (%) of oysters transplanted from OB 2 to NOB 2A, NOB 2B and NOB 2C from January 2010 to May 2010 in Mulky estuary

Months	NOB 2A	NOB 2B	NOB 2C
	Survival rate (%)	Survival rate (%)	Survival rate (%)
January 2010	100	100	100
February 2010	93.33	100	96.66
March 2010	93.33	96.66	93.33
April 2010	93.33	93.33	93.33
May 2010	93.33	90	93.33

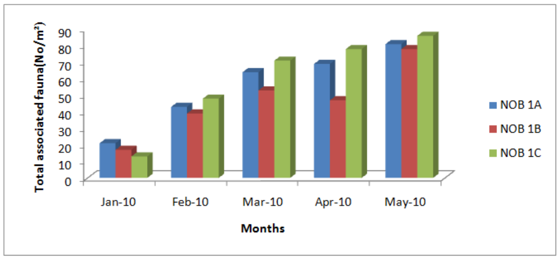

Fig.1. Monthly distribution of macrobenthos at NOB 1A, NOB 1B and NOB 1C from January 2010 to May 2010

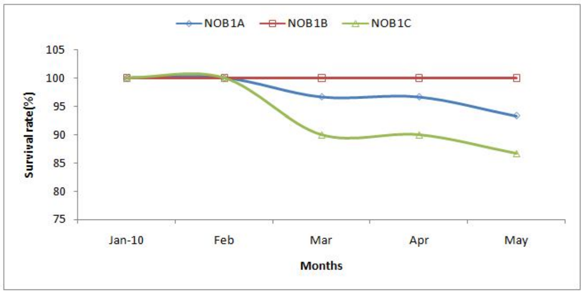

Fig.2. Survival rate (%) of oysters transplanted from OB 1 to NOB 1A, NOB 1B and NOB 1C from January 2010 to May 2010 in Mulky estuary

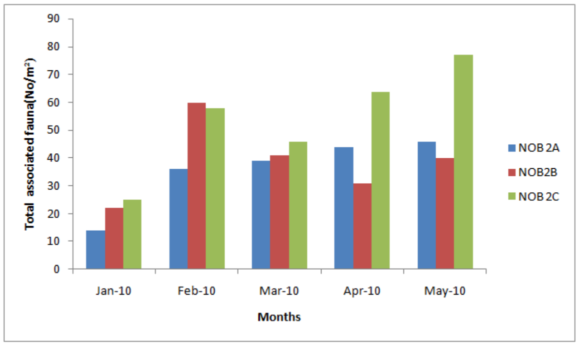

Fig.3. Monthly distribution of macrobenthos at NOB 2A, NOB 2B and NOB 2C from January 2010 to May 2010

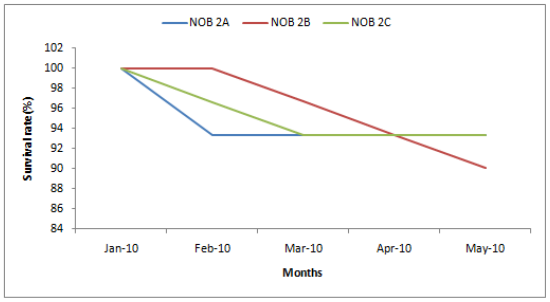

Fig.4. Survival rate (%) of oysters transplanted from OB 2 to NOB 2A, NOB 2B and NOB 2C from January 2010 to May 2010 in Mulky estuary

Moreover, the significant positive correlation was recorded between growth of the transplanted oysters and above mentioned environmental factors in all the experimental cages. At the non-oyster beds, the population density of the macrobenthos varied from 36 to 86 No/ m². It was observed that the population density and species of macrobenthos increased over the months indicating the better association with transplanted oysters. This indicates that the transplanted oysters may also support macrobenthos just like native oyster beds. Thus, transplantation of oysters from oyster bed areas to non-oyster bed areas may be taken up to enhance the abundance of oyster population in Mulky estuary. Recently, in Mulky estuary, the monthly distribution of macrobenthos at oyster beds was recorded from October 2008 to April 2010 and found that the molluscs were dominant throughout the study period followed by crustaceans and polychaetes. The population density of the macrobenthos at oyster beds was ranged from 18 to 386 No/m²(Ganapathi Naik, 2012). However, in the present study also molluscs were dominant throughout the study period followed by crustaceans and polychaetes with transplanted oysters. Dame (1996) reported an average of 2,949 /m² macrobenthos in the intertidal oyster beds of South Carolina. Bahr (1974) reported an average 24,747/ m² of macrobenthos in the oyster beds of Georgia, USA. The reported density of macrobenthos in oyster beds of South Carolina and Georgia, USA was quite higher than the density reported in the present study. This may be due to temperate oyster beds provide shelter for large number of fauna. Moreover, population density of the macrobenthos is also influenced by the water exchange in the estuary. Cerco and Noel (2005) reported that oysters composed a majority of harvests in many areas in USA and Europe. Oysters are ecosystem engineers that influence ecological processes such as maintenance of biodiversity, population and food web dynamics, nutrient cycling and water quality maintenance (Mann and Powell, 2007; Ronaldo *et al*., 2010).

Brumbaugh and Toropova (2008) opinied that the oysters would be successful, high-impact members of recipient ecosystems. In the present investigation, the experiments revealed that in Mulky estuary, oysters could be transplanted from oyster beds to non- oyster bed areas to enhance wild stocks of oysters that in turn beneficial for fishermen for commercial harvesting. Since, oyster populations contribute to maintain the water quality through filtering the water, the enhanced oyster population through transplantation may also contribute in maintaining the water quality of Mulky estuary. Furthermore, oyster beds support rich biodiversity especially benthic communities, the enhanced natural oyster stocks may support high level of biodiversity in Mulky estuary that may sustain the ecosystem health. Further, oyster culture and transplantation together may substantially enhance the oyster production in Mulky estuary.

Conclusion

The substantial assemblages of macorbenthos with transplanted oysters in Mulky estuary indicate the possibility of healthy growth and survival of transplanted oysters from oyster beds to non-oyster bed areas. Higher population density of macrobenthos is an indication of overall health of the oyster beds. In the present study, population density and species diversity gradually increased over the months indicating sustenance of oysters in transplanted environment. However, oyster transplantation is important to enhance the population abundance and also to maintain the water quality. In Mulky estuary, better assemblages of macrobenthos with transplanted oysters revealed the possibility of large scale transplantation of oysters that may uplift the livelihoods of fishers.

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