Chapter 11
Human Population and the Environment

Abstract One of the burning issues of the present world is the explosion of human population due to which shortage of resources in terms of food, space, employment and other basic needs has cropped up. The chapter discusses a comprehensive population policy, which is based not on the traditional foundation of family planning, but on the pillars of women's access to education, health care, economic and political decisions. To solve the acute unemployment problem, a non-conventional alternative livelihood has also been presented as annexure to the chapter.

Keywords COVID-19 · Family planning · J-shaped growth curve · Population explosion · S-shaped growth curve

11.1 Population Growth Forms

Population is a more or less a permanent aggregation of individuals of the same species inhabiting a specific geographic area at a given time. Population ecology is the study of various factors affecting growth, distribution, natality, dispersal and mortality of individuals constituting the population. Population of a species at a specific place is never static. It is extremely dynamic and depicts variation of its size and density with time due to influence of various abiotic and biotic factors. Favourable environmental condition increases population growth whereas unfavourable conditions decrease population growth. Populations of different species inhabiting a specific common area constitute biotic community.

The accelerating pace of population growth in the last century was not due to any undue rise in birth rate of world population, but, because in the last century, there was a sharp fall in death rate, advancements in healthcare control over fatal diseases such as small pox, plague and cholera and improved food distribution system (result of food security). The average number of children born to a mother has declined from 5 to 3.5 since 1950, though the size of world population has more than doubled during the same period. However, when we are in the process of writing down this chapter the appalling shadow of Corona virus attack has

A. Mitra, S. Zaman, *Environmental Science - A Ground Zero Observation on the Indian Subcontinent*, https://doi.org/10.1007/978-3-030-49131-4_11

already taken the lives of 37,820 individuals throughout the world (https://www.worldometers.info/coronavirus/ Last updated: March 31, 2020, 04:32 GMT), which is a phase of retardation in the growing population scenario of the planet. Country-wise report of this pandemic event is highlighted in Annexure 11B.

11.1.1 Characteristics of Population

11.1.1.1 Natality (Birth Rate)

Natality is average rate of reproduction or birth per unit time. It increases the size of population. The offspring may be produced by birth, hatching or germination. The maximum natality rate achieved under ideal conditions is termed fecundity or potential natality or biotic natality.

The factors (shortage of food and living space, predation, competition, emigration, natural death, natural calamities and carrying capacity) preventing a species from achieving a potential natality are called environmental resistance or population regulation.

11.1.1.2 Mortality (Death Rate)

Mortality is the average number of individuals that die or get killed naturally per unit time. It is basically the ratio of deaths in an area to the population of that area and is expressed per 1000 per year.

11.1.1.3 Density

Density is the number of individuals of a particular species per unit area at a given time. Population density (D) can be calculated by counting all individuals present at a given time in a specific space and dividing it by the number of units of area or space (S). The units of space may be cm^2, m^2 or km^2. For example, earthworms can be in thousands in an acre of land.

11.1.1.4 Dispersal

Population of a place is never static. Its size goes on changing due to movement of organisms into or out of a population under the influence of various abiotic and biotic factors. This process is termed population dispersal. Dispersal is of three types:

- Emigration, i.e. permanent exit of some individuals from local population. The size of local population decreases.
- Immigration, i.e. permanent entry of addition individuals from outside into a given population. It increases the size of local population.
- Migration: migration involves two-way moment of the entire population. It is very common in birds and fishes.

11.1.1.5 Sex Ratio

The ratio of females to males in a population is termed as sex ratio. In 1981 in India, it was 934 females per 1000 males, while in 1991 it came down to 929 females per 1000 males. But after two decades in 2012, it rose to 940 females per 1000 males.

11.1.1.6 Age Ratio

The age structure if a given population refers to the proportion of individuals of different ages within that population. It indicates the ratio of different age groups recognized on the basis of the ability to produce. They are as follows:

11.1.1.7 Pre-reproductive Age

This is the juvenile stage of population. This comprises infants/adolescents who have not attained puberty and thus they are not capable of reproducing.

11.1.1.8 Reproductive Age

This is the age group comprising individuals capable of producing young ones.

11.1.1.9 Post-reproductive Age

This age group includes individuals who have lost the capacity to produce young ones.

Age distribution is an important characteristic of population. It affects both natality and mortality rate. Age ratio determines the reproductive capacity of the population.

11.1.1.10 Age Pyramids

The graphic representation of percentage of different age groups mentioned above is termed age pyramid.

Age pyramids are of three types:

- Triangular age pyramid (population growth is positive, e.g. India)
- Bell-shaped age pyramid (population growth is zero)
- Urn-shaped age pyramid (population growth is negative)

11.1.1.11 Population Growth

Population growth is the increase in number of individuals. The rate of growth is measured by an increase in the number of individuals in a population per unit time. For controlling the growth of population, natality and mortality are important factors. The percentage ratio of natality and mortality is termed vital index.

$$\text{Vital index} = \text{Natality} / \text{Mortality} \times 100$$

- If natality + immigration is greater (>) than mortality + emigration, the growth is positive.
- If natality + immigration is lesser (<) than mortality + emigration, the growth is negative.
- If natality + immigration is equal (=) to mortality + emigration, the growth is zero.

Average annual growth rate of human population can be calculated as follows:

$$\text{Average annual growth rate}(\%) = (\text{P1} - \text{P2}) / (\text{P1} \times \text{N}) \times 100$$

P1 is population size in the previous census.
P2 is population size in the present census.
N is the number of years between the two censuses.

The size of local population is affected not only by immigration, emigration, natality, mortality and biotic factors but also by environmental resistance and carrying capacity. Population growth is the result of interaction of biotic potential and environmental resistance. Two distinct patterns of population growth are identified.

11.1.1.12 S-Shaped Growth (Sigmoid)

This is the most common growth pattern (Fig. 11.1). Sigmoid growth has been divided into four phases.

- Early or lag phase (population increases slowly and population size small)
- Exponential or log phase (population growth increases)
- Diminishing growth phase (population growth rate decrease)
- Equilibrium/stationary phase (natality and mortality rates are at equilibrium, population growth zero)

11.1.1.13 J-Shaped Growth

J-shaped growth pattern has been distinct phases.

- Early lag phase
- Exponential (log) phase
- Crash phase

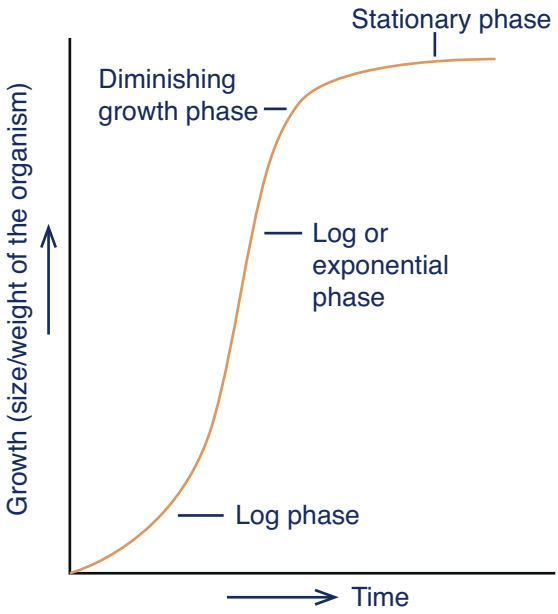

Fig. 11.1 S-Shaped Growth (Sigmoid)

This type of growth (Fig. 11.2) is found in algal bloom, seasonal annual plants and insect, etc.

11.2 Scenario of Global Population

The distribution of population in the world is highly non-uniform. Some areas are very thickly populated while some are sparsely populated. There are various reasons behind uneven distribution of population that can be can be categorized in to geographical factors, social and cultural factors and economic factors. The geographical factors include favourable topography, availability of mineral and freshwater resources, favourable climate soil fertility and food security that invite population and help to flourish. Indo-Gangetic Plains, Diamond Mines of South Africa, etc. are densely populated regions. The social and cultural factors encompass areas of better housing, education and health facilities and religious harmony. Places of religious and cultural significance also attract people, e.g. Varanasi, Jerusalem, etc. The economic factors also invite population due to presence of more industries, transportation and communication facilities, employment opportunities, etc.

The scenario of the present day world has changed a lot since the last few centuries. The population has increased exponentially (Table 11.1), while the area (space) remained constant (Table 11.2).

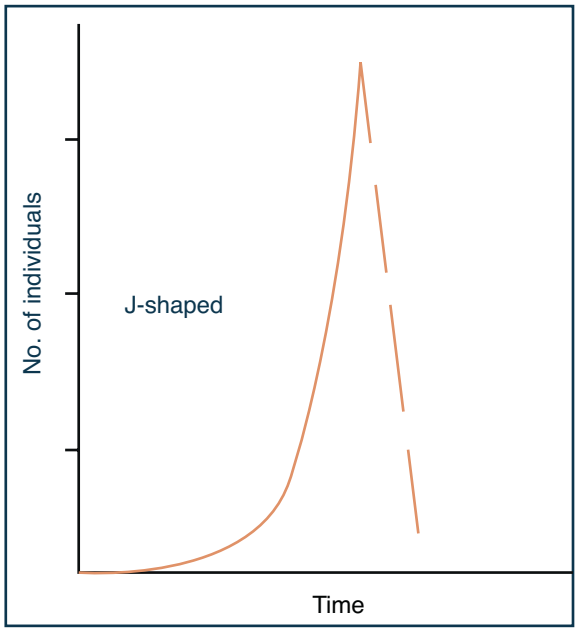

Fig. 11.2 J-Shaped Growth (Sigmoid)

This has hiked up the population density and created a great pressure and challenges on leaving space, resources, environmental condition, job opportunity, mobility and the quality of life.

The predicted scenario of world population in 2050 looks very alarming. The global population is expected to be around 9.80 billion people, which is 2 billion more than the present population as recorded on September 24, 2019, which is 7,732,640,485 at 3.09 pm IST from the site worldpopulationreview.com. It is expected that India will surpass China as the most populated country in the world with a population of 1.66 billion people compared to China who will occupy the second position with a population of 1.36 billion. Nigeria will become the world's third most populous country in 2050 with a population of 4.10 million people. The fourth position will be occupied by the United States with a population of 390 million people. Vatican City has been predicted to continue being the least populated country in the World in 2050. Presently it is having a negative growth rate in the population domain and in 2050 it will have only 800 people. The overall population will increase globally due to development in the health sector and technology. Better healthcare is the road map for reducing death rate and infant mortality. Many predictions on the world population scenario are still waiting with the advancement in computer application, artificial intelligence and environment. However, it is no exaggeration to say that if the population follows the present increasing trend then there will be an acute shortage of resources in terms of space, food and various basic needs. High-end technological development in the field of agriculture, fishery and other food items coupled with International-level policy of population transference

Table 11.1 Increase of population in 1 year (in %)

Country	2017	2018
Aruba	105,366	105,845
Afghanistan	36,296,400	37,172,386
Angola	29,816,748	30,809,762
Albania	2,873,457	2,866,376
Andorra	77,001	77,006
Arab World	411,898,965	419,790,588
United Arab Emirates	9,487,203	9,630,959
Argentina	44,044,811	44,494,502
Armenia	2,944,809	2,951,776
American Samoa	55,620	55,465
Antigua and Barbuda	95,426	96,286
Australia	24,601,860	24,992,369
Austria	8,797,566	8,847,037
Azerbaijan	9,854,033	9,942,334
Burundi	10,827,024	11,175,378
Belgium	11,375,158	11,422,068
Benin	11,175,204	11,485,048
Burkina Faso	19,193,284	19,751,535
Bangladesh	159,670,593	161,356,039
Bulgaria	7,075,947	7,024,216
Bahrain	1,494,074	1,569,439
Bahamas, The	381,761	385,640
Bosnia and Herzegovina	3,351,527	3,323,929
Belarus	9,498,264	9,485,386
Belize	375,769	383,071
Bermuda	63,874	63,968
Bolivia	11,192,854	11,353,142
Brazil	207,833,831	209,469,333
Barbados	286,233	286,641
Brunei Darussalam	424,473	428,962
Bhutan	745,568	754,394
Botswana	2,205,128	2,254,126
Central African Republic	4,596,028	4,666,377
Canada	36,540,268	37,058,856
Central Europe and the Baltics	102,738,854	102,511,922
Switzerland	8,451,840	8,516,543
Channel Islands	168,665	170,499
Chile	18,470,439	18,729,160
China	1,386,395,000	1,392,730,000
Cote d'Ivoire	24,437,469	25,069,229
Cameroon	24,566,045	25,216,237
Congo, Dem. Rep.	81,398,764	84,068,091

(continued)

Table 11.1 (continued)

Country	2017	2018
Congo, Rep.	5,110,702	5,244,363
Colombia	48,901,066	49,648,685
Comoros	813,892	832,322
Cabo Verde	537,497	543,767
Costa Rica	4,949,954	4,999,441
Caribbean small states	7,314,990	7,358,965
Cuba	11,339,259	11,338,138
Curacao	160,175	159,849
Cayman Islands	63,382	64,174
Cyprus	1,179,680	1,189,265
Czech Republic	10,594,438	10,625,695
Germany	82,657,002	82,927,922
Djibouti	944,097	958,920
Dominica	71,458	71,625
Denmark	5,764,980	5,797,446
Dominican Republic	10,513,131	10,627,165
Algeria	41,389,198	42,228,429
East Asia and Pacific (excluding high income)	2,068,155,660	2,081,651,801
Early-demographic dividend	3,207,188,541	3,249,140,605
East Asia and Pacific	2,314,202,003	2,328,220,870
Europe and Central Asia (excluding high income)	415,710,935	417,797,257
Europe and Central Asia	915,420,161	918,793,590
Ecuador	16,785,361	17,084,357
Egypt, Arab Rep.	96,442,593	98,423,595
Euro area	341,164,362	341,783,171
Eritrea		
Spain	46,593,236	46,723,749
Estonia	1,317,384	1,320,884
Ethiopia	106,400,024	109,224,559
European Union	512,191,098	513,213,363
Fragile and conflict-affected situations	504,119,229	515,215,936
Finland	5,508,214	5,518,050
Fiji	877,459	883,483
France	66,865,144	66,987,244
Faroe Islands	48,331	48,497
Micronesia, Fed. Sts.	111,459	112,640
Gabon	2,064,823	2,119,275
United Kingdom	66,058,859	66,488,991
Georgia	3,728,004	3,731,000
Ghana	29,121,471	29,767,108
Gibraltar	33,728	33,718
Guinea	12,067,539	12,414,318

(continued)

Table 11.1 (continued)

Country	2017	2018
Gambia, The	2,213,894	2,280,102
Guinea-Bissau	1,828,146	1,874,309
Equatorial Guinea	1,262,001	1,308,974
Greece	10,754,679	10,727,668
Grenada	110,874	111,454
Greenland	56,171	56,025
Guatemala	16,914,936	17,247,807
Guam	164,281	165,768
Guyana	775,221	779,004
High income	1,204,429,565	1,210,312,147
Hong Kong SAR, China	7,391,700	7,451,000
Honduras	9,429,013	9,587,522
Heavily indebted poor countries (HIPC)	759,106,221	780,234,406
Croatia	4,124,531	4,089,400
Haiti	10,982,366	11,123,176
Hungary	9,787,966	9,768,785
IBRD only	4,731,120,193	4,772,284,113
IDA and IBRD total	6,335,039,629	6,412,522,234
IDA total	1,603,919,436	1,640,238,121
IDA blend	543,525,897	555,830,605
Indonesia	264,645,886	267,663,435
IDA only	1,060,393,539	1,084,407,516
Isle of Man	83,598	84,077
India	1,338,658,835	1,352,617,328
Not classified		
Ireland	4,807,388	4,853,506
Iran, Islamic Rep.	80,673,951	81,800,269
Iraq	37,552,781	38,433,600
Iceland	343,400	353,574
Israel	8,713,300	8,883,800
Italy	60,536,709	60,431,283
Jamaica	2,920,853	2,934,855
Jordan	9,779,173	9,956,011
Japan	126,785,797	126,529,100
Kazakhstan	18,037,776	18,276,499
Kenya	50,221,473	51,393,010
Kyrgyz Republic	6,198,200	6,315,800
Cambodia	16,009,414	16,249,798
Kiribati	114,158	115,847
St. Kitts and Nevis	52,045	52,441
Korea, Rep.	51,466,201	51,635,256
Kuwait	4,056,097	4,137,309

(continued)

Table 11.1 (continued)

Country	2017	2018
Latin America and Caribbean (excluding high income)	603,254,104	609,013,934
Lao PDR	6,953,035	7,061,507
Lebanon	6,811,873	6,848,925
Liberia	4,702,228	4,818,977
Libya	6,580,724	6,678,567
St. Lucia	180,955	181,889
Latin America and Caribbean	635,372,515	641,357,515
Least developed countries: UN classification	986,365,080	1,009,662,578
Low income	687,449,530	705,417,321
Liechtenstein	37,800	37,910
Sri Lanka	21,444,000	21,670,000
Lower middle income	2,981,420,591	3,022,905,169
Low and middle income	6,306,560,891	6,383,958,209
Lesotho	2,091,412	2,108,132
Late-demographic dividend	2,276,319,334	2,288,665,963
Lithuania	2,828,403	2,789,533
Luxembourg	596,336	607,728
Latvia	1,942,248	1,926,542
Macao SAR, China	622,585	631,636
St. Martin (French part)	36,560	37,264
Morocco	35,581,294	36,029,138
Monaco	38,392	38,682
Moldova	3,549,196	3,545,883
Madagascar	25,570,540	26,262,368
Maldives	496,402	515,696
Middle East and North Africa	441,255,234	448,912,859
Mexico	124,777,324	126,190,788
Marshall Islands	58,058	58,413
Middle income	5,619,111,361	5,678,540,888
North Macedonia	2,081,996	2,082,958
Mali	18,512,394	19,077,690
Malta	467,999	483,530
Myanmar	53,382,581	53,708,395
Middle East and North Africa (excluding high income)	376,546,755	382,896,715
Montenegro	622,373	622,345
Mongolia	3,113,779	3,170,208
Northern Mariana Islands	56,562	56,882
Mozambique	28,649,007	29,495,962
Mauritania	4,282,574	4,403,319
Mauritius	1,264,613	1,265,303
Malawi	17,670,260	18,143,315
Malaysia	31,105,028	31,528,585

(continued)

Table 11.1 (continued)

Country	2017	2018
North America	361,751,263	364,290,258
Namibia	2,402,603	2,448,255
New Caledonia	280,350	284,060
Niger	21,602,472	22,442,948
Nigeria	190,873,311	195,874,740
Nicaragua	6,384,855	6,465,513
Netherlands	17,131,296	17,231,017
Norway	5,276,968	5,314,336
Nepal	27,627,124	28,087,871
Nauru	12,876	12,704
New Zealand	4,793,900	4,885,500
OECD members	1,296,225,760	1,303,529,456
Oman	4,665,935	4,829,483
Other small states	30,148,800	30,758,989
Pakistan	207,896,686	212,215,030
Panama	4,106,771	4,176,873
Peru	31,444,297	31,989,256
Philippines	105,173,264	106,651,922
Palau	17,808	17,907
Papua New Guinea	8,438,029	8,606,316
Poland	37,974,826	37,978,548
Pre-demographic dividend	894,512,725	919,485,393
Puerto Rico	3,325,001	3,195,153
Korea, Dem. People's Rep.	25,429,985	25,549,819
Portugal	10,300,300	10,281,762
Paraguay	6,867,062	6,956,071
West Bank and Gaza	4,454,805	4,569,087
Pacific island small states	2,422,086	2,457,367
Post-demographic dividend	1,106,035,186	1,109,997,273
French Polynesia	276,103	277,679
Qatar	2,724,724	2,781,677
Romania	19,587,491	19,473,936
Russian Federation	144,496,740	144,478,050
Rwanda	11,980,937	12,301,939
South Asia	1,792,835,608	1,814,388,744
Saudi Arabia	33,099,147	33,699,947
Sudan	40,813,396	41,801,533
Senegal	15,419,381	15,854,360
Singapore	5,612,253	5,638,676
Solomon Islands	636,038	652,858
Sierra Leone	7,488,431	7,650,154
El Salvador	6,388,122	6,420,744

(continued)

Table 11.1 (continued)

Country	2017	2018
San Marino	33,671	33,785
Somalia	14,589,119	15,008,154
Serbia	7,020,858	6,982,084
Sub-Saharan Africa (excluding high income)	1,050,057,829	1,078,209,758
South Sudan	10,910,759	10,975,920
Sub-Saharan Africa	1,050,153,672	1,078,306,520
Small states	39,885,876	40,575,321
Sao Tome and Principe	207,089	211,028
Suriname	570,496	575,991
Slovak Republic	5,439,232	5,447,011
Slovenia	2,066,388	2,067,372
Sweden	10,057,698	10,183,175
Eswatini	1,124,753	1,136,191
Sint Maarten (Dutch part)	40,574	40,654
Seychelles	95,843	96,762
Syrian Arab Republic	17,068,002	16,906,283
Turks and Caicos Islands	37,115	37,665
Chad	15,016,773	15,477,751
East Asia and Pacific (IDA and IBRD countries)	2,042,687,863	2,056,064,424
Europe and Central Asia (IDA and IBRD countries)	457,810,292	459,865,205
Togo	7,698,475	7,889,094
Thailand	69,209,858	69,428,524
Tajikistan	8,880,268	9,100,837
Turkmenistan	5,757,669	5,850,908
Latin America and the Caribbean (IDA and IBRD countries)	619,460,244	625,569,713
Timor-Leste	1,243,261	1,267,972
Middle East and North Africa (IDA and IBRD countries)	372,091,950	378,327,628
Tonga	101,998	103,197
South Asia (IDA and IBRD)	1,792,835,608	1,814,388,744
Sub-Saharan Africa (IDA and IBRD countries)	1,050,153,672	1,078,306,520
Trinidad and Tobago	1,384,072	1,389,858
Tunisia	11,433,443	11,565,204
Turkey	81,101,892	82,319,724
Tuvalu	11,370	11,508
Tanzania	54,663,906	56,318,348
Uganda	41,162,465	42,723,139
Ukraine	44,831,135	44,622,516
Upper middle income	2,637,690,770	2,655,635,719
Uruguay	3,436,646	3,449,299
United States	325,147,121	327,167,434
Uzbekistan	32,388,600	32,955,400
St. Vincent and the Grenadines	109,827	110,210

(continued)

Table 11.1 (continued)

Country	2017	2018
Venezuela, RB	29,390,409	28,870,195
British Virgin Islands	29,577	29,802
Virgin Islands (USA)	107,268	106,977
Vietnam	94,596,642	95,540,395
Vanuatu	285,510	292,680
World	7,510,990,456	7,594,270,356
Samoa	195,352	196,130
Kosovo	1,830,700	1,845,300
Yemen, Rep.	27,834,821	28,498,687
South Africa	57,000,451	57,779,622
Zambia	16,853,688	17,351,822
Zimbabwe	14,236,745	14,439,018

(from densely populated ecosystem to sparsely populated ecosystem) may provide a pathway to combat the threats of population explosion in 2050.

11.3 Concept of Population Control

The explosion of population in majority of the regions in the world is a matter of great concern as it is directly linked with dark chapters like poverty, job insecurity, pollution, scarcity of resources (food, space, water, etc.) and health hazards. We therefore initiated an in-depth study to scan the growth of population in different regions of the world. This data bank is sourced from CIA World Fact book and unless otherwise noted, information in this table is accurate as of January 1, 2019. Our first order analysis reflects an alarming growth of population (1 or more than 1%) in 106 countries including India (Table 11.3). This will definitely create a burden on the resource reservoir of the planet if not controlled through proper policy. Rather than simply equating population policy with family planning, the new thinking is to address some of the roots of the problem like improving women's access to education, healthcare and economic and political decisions.

Family planning is a good initiative to check the accelerating phase of population growth. The History of family planning begins from the middle of nineteenth century. The Malthusian League was founded in England in 1860 to spread the message of birth control. According to Malthus theory 'Population tends to increase geometrically while food supply increases arithmetically'. Similar efforts were also made in Sweden and France. The objective was to check/control rapid population growth and care for the health of pregnant mothers.

After World War II (1939–1945), family planning gained momentum in many countries of Asia, Africa and elsewhere. India was the first country to adopt family planning in 1951 as a National Policy. China, though initially opposed to family

Table 11.2 Country-wise area per sq. mi with population density (PD)

Country	Area (sq. mi)	PD (per sq. mi)
Afghanistan	647,500	48.0
Albania	28,748	124.6
Algeria	2,381,740	13.8
American Samoa	199	290.4
Andorra	468	152.1
Angola	1,246,700	9.7
Anguilla	102	132.1
Antigua and Barbuda	443	156.0
Argentina	2,766,890	14.4
Armenia	29,800	99.9
Aruba	193	372.5
Australia	7,686,850	2.6
Austria	83,870	97.7
Azerbaijan	86,600	91.9
Bahamas, The	13,940	21.8
Bahrain	665	1050.5
Bangladesh	144,000	1023.4
Barbados	431	649.5
Belarus	207,600	49.6
Belgium	30,528	340.0
Belize	22,966	12.5
Benin	112,620	69.8
Bermuda	53	1241.0
Bhutan	47,000	48.5
Bolivia	1,098,580	8.2
Bosnia and Herzegovina	51,129	88.0
Botswana	600,370	2.7
Brazil	8,511,965	22.1
British Virgin Is.	153	151.0
Brunei	5770	65.8
Bulgaria	110,910	66.6
Burkina Faso	274,200	50.7
Burma	678,500	69.8
Burundi	27,830	290.7
Cambodia	181,040	76.7
Cameroon	475,440	36.5
Canada	9,984,670	3.3
Cape Verde	4033	104.4
Cayman Islands	262	173.4
Central African Rep.	622,984	6.9
Chad	1,284,000	7.7

(continued)

Table 11.2 (continued)

Country	Area (sq. mi)	PD (per sq. mi)
Chile	756,950	21.3
China	9,596,960	136.9
Colombia	1,138,910	38.3
Comoros	2170	318.4
Congo, Dem. Rep.	2,345,410	26.7
Congo, Repub. of the	342,000	10.8
Cook Islands	240	89.1
Costa Rica	51,100	79.8
Cote d'Ivoire	322,460	54.8
Croatia	56,542	79.5
Cuba	110,860	102.7
Cyprus	9250	84.8
Czech Republic	78,866	129.8
Denmark	43,094	126.5
Djibouti	23,000	21.2
Dominica	754	91.4
Dominican Republic	48,730	188.5
East Timor	15,007	70.8
Ecuador	283,560	47.8
Egypt	1,001,450	78.8
El Salvador	21,040	324.3
Equatorial Guinea	28,051	19.3
Eritrea	121,320	39.5
Estonia	45,226	29.3
Ethiopia	1,127,127	66.3
Faroe Islands	1399	33.8
Fiji	18,270	49.6
Finland	338,145	15.5
France	547,030	111.3
French Guiana	91,000	2.2
French Polynesia	4167	65.9
Gabon	267,667	5.3
Gambia, The	11,300	145.3
Gaza Strip	360	3968.8
Georgia	69,700	66.9
Germany	357,021	230.9
Ghana	239,460	93.6
Gibraltar	7	3989.7
Greece	131,940	81.0
Greenland	2,166,086	0.0
Grenada	344	260.8

(continued)

Table 11.2 (continued)

Country	Area (sq. mi)	PD (per sq. mi)
Guadeloupe	1780	254.4
Guam	541	316.1
Guatemala	108,890	112.9
Guernsey	78	838.6
Guinea	245,857	39.4
Guinea-Bissau	36,120	39.9
Guyana	214,970	3.6
Haiti	27,750	299.4
Honduras	112,090	65.4
Hong Kong	1092	6355.7
Hungary	93,030	107.3
Iceland	103,000	2.9
India	3,287,590	333.2
Indonesia	1,919,440	127.9
Iran	1,648,000	41.7
Iraq	437,072	61.3
Ireland	70,280	57.8
Isle of Man	572	131.9
Israel	20,770	305.8
Italy	301,230	193.0
Jamaica	10,991	250.9
Japan	377,835	337.4
Jersey	116	785.2
Jordan	92,300	64.0
Kazakhstan	2,717,300	5.6
Kenya	582,650	59.6
Kiribati	811	130.0
Korea, North	120,540	191.8
Korea, South	98,480	496.0
Kuwait	17,820	135.7
Kyrgyzstan	198,500	26.3
Laos	236,800	26.9
Latvia	64,589	35.2
Lebanon	10,400	372.5
Lesotho	30,355	66.6
Liberia	111,370	27.3
Libya	1,759,540	3.4
Liechtenstein	160	212.4
Lithuania	65,200	55.0
Luxembourg	2586	183.5
Macau	28	16183.0

(continued)

Table 11.2 (continued)

Country	Area (sq. mi)	PD (per sq. mi)
Macedonia	25,333	80.9
Madagascar	587,040	31.7
Malawi	118,480	109.8
Malaysia	329,750	74.0
Maldives	300	1196.7
Mali	1,240,000	9.5
Malta	316	1266.5
Marshall Islands	11,854	5.1
Martinique	1100	396.5
Mauritania	1,030,700	3.1
Mauritius	2040	608.3
Mayotte	374	538.1
Mexico	1,972,550	54.5
Micronesia, Fed. St.	702	153.9
Moldova	33,843	132.0
Monaco	2	16271.5
Mongolia	1,564,116	1.8
Montserrat	102	92.5
Morocco	446,550	74.4
Mozambique	801,590	24.6
Namibia	825,418	2.5
Nauru	21	632.7
Nepal	147,181	192.2
Netherlands	41,526	397.1
Netherlands Antilles	960	231.0
New Caledonia	19,060	11.5
New Zealand	268,680	15.2
Nicaragua	129,494	43.0
Niger	1,267,000	9.9
Nigeria	923,768	142.7
N. Mariana Islands	477	172.9
Norway	323,802	14.2
Oman	212,460	14.6
Pakistan	803,940	206.2
Palau	458	44.9
Panama	78,200	40.8
Papua New Guinea	462,840	12.3
Paraguay	406,750	16.0
Peru	1,285,220	22.0
Philippines	300,000	298.2
Poland	312,685	123.3

(continued)

Table 11.2 (continued)

Country	Area (sq. mi)	PD (per sq. mi)
Portugal	92,391	114.8
Puerto Rico	13,790	284.8
Qatar	11,437	77.4
Reunion	2517	312.9
Romania	237,500	93.9
Russia	17,075,200	8.4
Rwanda	26,338	328.4
Saint Helena	413	18.2
Saint Kitts and Nevis	261	149.9
Saint Lucia	616	273.5
St Pierre and Miquelon	242	29.0
Saint Vincent and the Grenadines	389	303.0
Samoa	2944	60.1
San Marino	61	479.5
Sao Tome and Principe	1001	193.2
Saudi Arabia	1,960,582	13.8
Senegal	196,190	61.1
Serbia	88,361	106.3
Seychelles	455	179.2
Sierra Leone	71,740	83.7
Singapore	693	6482.2
Slovakia	48,845	111.4
Slovenia	20,273	99.2
Solomon Islands	28,450	19.4
Somalia	637,657	13.9
South Africa	1,219,912	36.2
Spain	504,782	80.0
Sri Lanka	65,610	308.2
Sudan	2,505,810	16.5
Suriname	163,270	2.7
Swaziland	17,363	65.5
Sweden	449,964	20.0
Switzerland	41,290	182.2
Syria	185,180	102.0
Taiwan	35,980	640.3
Tajikistan	143,100	51.2
Tanzania	945,087	39.6
Thailand	514,000	125.7
Togo	56,785	97.7
Tonga	748	153.3

(continued)

Table 11.2 (continued)

Country	Area (sq. mi)	PD (per sq. mi)
Trinidad and Tobago	5128	207.9
Tunisia	163,610	62.2
Turkey	780,580	90.2
Turkmenistan	488,100	10.3
Turks and Caicos Is	430	49.2
Tuvalu	26	454.2
Uganda	236,040	119.5
Ukraine	603,700	77.4
United Arab Emirates	82,880	31.4
United Kingdom	244,820	247.6
United States	9,631,420	31.0
Uruguay	176,220	19.5
Uzbekistan	447,400	61.0
Vanuatu	12,200	17.1
Venezuela	912,050	28.2
Vietnam	329,560	256.1
Virgin Islands	1910	56.9
Wallis and Futuna	274	58.5
West Bank	5860	419.9
Western Sahara	266,000	1.0
Yemen	527,970	40.6
Zambia	752,614	15.3
Zimbabwe	390,580	31.3

planning in the line with its communist ideology, went for it in 1962, a more aggressive policy of 'one child for one couple'. Family planning methods were facilitated by advancements in sterilization, intrauterine device, pills and condoms.

In India, family planning was given special place in the country's first 5-year plan (1951–1956). It was placed under the control of Ministry of Health and, in 1977, its nomenclature was changed to Ministry of Health and Family Welfare. All expenditure on family planning programme is borne by the Union Government. The States and Union Territories are only implementing agencies. A vast infrastructure exists in the form of community health centre, primary health centre and sub-centres.

Family planning measures include adoption of a number of contraceptive devices for preventing unwanted births. The success of these measures depends upon various socio-economic factors like education, industrial development, employments, etc.

The United Nations has played a very crucial role in popularizing family planning. This organization not only worked for creating awareness about the population problem but also provided technical and financial support for the purpose. Some of the important family planning movements are:

Table 11.3 Country-wise population growth rate (in %)

Rank	Country	Population growth rate
1	Syria	7.37
2	Angola	3.49
3	Malawi	3.31
4	Burundi	3.23
5	Chad	3.23
6	Uganda	3.18
7	Niger	3.16
8	Mali	2.98
9	Sudan	2.93
10	Zambia	2.91
11	Ethiopia	2.83
12	Burkina Faso	2.76
13	Guinea	2.75
14	Tanzania	2.74
15	Gabon	2.73
16	Benin	2.68
17	Western Sahara	2.64
18	Togo	2.61
19	Liberia	2.59
20	Cameroon	2.54
21	Nigeria	2.54
22	Iraq	2.5
23	Guinea-Bissau	2.48
24	Mozambique	2.46
25	Madagascar	2.46
26	Equatorial Guinea	2.41
27	Sierra Leone	2.4
28	Egypt	2.38
29	Afghanistan	2.37
30	Senegal	2.36
31	Congo	2.33
32	East Timor	2.32
33	Rwanda	2.3
34	Cote d'Ivoire	2.3
35	Gaza Strip	2.25
36	British Virgin Islands	2.2
37	Bahrain	2.19
38	Congo	2.17
39	Yemen	2.17
40	Ghana	2.16
41	Mauritania	2.14

(continued)

Table 11.3 (continued)

Rank	Country	Population growth rate
42	Djibouti	2.13
43	Central African Republic	2.11
44	Turks and Caicos Islands	2.09
45	Somalia	2.08
46	Jordan	2.02
47	Oman	2
48	Gambia	1.99
49	Cayman Islands	1.96
50	Qatar	1.95
51	Anguilla	1.92
52	Namibia	1.91
53	Solomon Islands	1.9
54	Luxembourg	1.9
55	West Bank	1.81
56	Vanuatu	1.81
57	Belize	1.8
58	Singapore	1.79
59	Guatemala	1.72
60	Zimbabwe	1.68
61	Papua New Guinea	1.67
62	Sao Tome and Principe	1.66
63	Saudi Arabia	1.63
64	Algeria	1.63
65	Tajikistan	1.58
66	Comoros	1.57
67	Kenya	1.57
68	Honduras	1.56
69	Brunei	1.55
70	Philippines	1.55
71	Botswana	1.52
72	Marshall Islands	1.5
73	Israel	1.49
74	Laos	1.48
75	Bolivia	1.48
76	Cambodia	1.48
77	Libya	1.45
78	United Arab Emirates	1.44
79	Pakistan	1.41
80	Kuwait	1.38
81	Malaysia	1.34
82	Cape Verde	1.32

(continued)

Table 11.3 (continued)

Rank	Country	Population growth rate
83	Haiti	1.31
84	New Caledonia	1.3
85	Ecuador	1.25
86	Aruba	1.24
87	Panama	1.24
88	Venezuela	1.21
89	Antigua and Barbuda	1.2
90	Iran	1.19
91	Paraguay	1.17
92	India	1.14
93	Costa Rica	1.13
94	Kiribati	1.12
95	Christmas Island	1.11
96	Mongolia	1.11
97	Ireland	1.11
98	Turkmenistan	1.1
99	Nepal	1.09
100	Mexico	1.09
101	Iceland	1.08
102	Bhutan	1.05
103	Bangladesh	1.02
104	Kyrgyzstan	1.02
105	Australia	1.01
106	Suriname	1
107	Malta	0.99
108	Dominican Republic	0.99
109	Kazakhstan	0.98
110	Colombia	0.97
111	Nicaragua	0.97
112	South Africa	0.97
113	Tunisia	0.95
114	Morocco	0.95
115	Norway	0.94
116	Peru	0.94
117	Uzbekistan	0.91
118	Vietnam	0.9
119	Eritrea	0.89
120	Argentina	0.89
121	Burma	0.89
122	Tuvalu	0.86
123	French Polynesia	0.85

(continued)

Table 11.3 (continued)

Rank	Country	Population growth rate
124	Indonesia	0.83
125	Azerbaijan	0.83
126	Swaziland	0.82
127	United States	0.8
128	Sweden	0.8
129	Bahamas, The	0.79
130	Liechtenstein	0.78
131	New Zealand	0.77
132	Jersey	0.76
133	Chile	0.75
134	Seychelles	0.74
135	Spain	0.73
136	Sri Lanka	0.73
137	Canada	0.72
138	Brazil	0.71
139	Macau	0.71
140	Saint Kitts and Nevis	0.7
141	San Marino	0.7
142	Switzerland	0.68
143	Belgium	0.67
144	Isle of Man	0.65
145	Samoa	0.61
146	Denmark	0.59
147	Faroe Islands	0.58
148	Mauritius	0.57
149	Fiji	0.56
150	Korea, North	0.52
151	Nauru	0.51
152	United Kingdom	0.51
153	Turkey	0.49
154	Guyana	0.48
155	Korea, South	0.44
156	Montserrat	0.43
157	Bermuda	0.43
158	Austria	0.42
159	Grenada	0.42
160	Palau	0.4
161	Netherlands	0.38
162	France	0.37
163	China	0.37
164	Finland	0.33

(continued)

Table 11.3 (continued)

Rank	Country	Population growth rate
165	Saint Lucia	0.31
166	Wallis and Futuna	0.3
167	Monaco	0.3
168	Albania	0.3
169	Hong Kong	0.29
170	Thailand	0.29
171	Guernsey	0.28
172	Uruguay	0.27
173	Barbados	0.26
174	El Salvador	0.25
175	Lesotho	0.24
176	Guam	0.23
177	Gibraltar	0.21
178	Macedonia	0.19
179	Dominica	0.17
180	Italy	0.16
181	Taiwan	0.15
182	Saint Helena	0.14
183	Czech Republic	0.1
184	Ukraine	0.04
185	Slovenia	0.03
186	Norfolk Island	0.01
187	Falkland Islands (Islas Malvinas)	0.01
188	Georgia	0.01
189	Cocos (Keeling) Islands	0
190	Pitcairn Islands	0
191	Vatican City	0
192	Tokelau	−0.01
193	Andorra	−0.01
194	Slovakia	−0.02
195	Svalbard	−0.03
196	Niue	−0.03
197	Greenland	−0.04
198	Jamaica	−0.05
199	Maldives	−0.06
200	Greece	−0.07
201	Tonga	−0.1
202	Russia	−0.11
203	Poland	−0.16
204	Germany	−0.17
205	Bosnia and Herzegovina	−0.17

(continued)

Table 11.3 (continued)

Rank	Country	Population growth rate
206	Trinidad and Tobago	−0.23
207	Saint Vincent and the Grenadines	−0.23
208	Belarus	−0.24
209	Japan	−0.24
210	Armenia	−0.25
211	Hungary	−0.26
212	Cuba	−0.27
213	Portugal	−0.27
214	Virgin Islands	−0.3
215	Montenegro	−0.34
216	Romania	−0.35
217	Serbia	−0.47
218	Croatia	−0.51
219	Northern Mariana Islands	−0.52
220	Micronesia	−0.55
221	Estonia	−0.6
222	Bulgaria	−0.63
223	Moldova	−1.06
224	Latvia	−1.1
225	Lithuania	−1.1
226	Saint Pierre and Miquelon	−1.13
227	South Sudan	−1.16
228	American Samoa	−1.35
229	Puerto Rico	−1.7
230	Cook Islands	−2.72
231	Lebanon	−3.13

1. Oral contraceptives (polls) introduced in 1960.
2. Plastic IUDs made available in 1961.
3. United Nations Fund for Population Activities (UNFPA) was created in 1961.
4. First World conference on population was organized by UNs at Bucharest (Romania) in 1974.
5. China started ‘one child for one couple’ campaign in 1979.
6. Second World War conference on population was organized by the UNs at Mexico in 1984.
7. Third World Conference on population was organized by the UNs at Cairo (Egypt) in 1994.
8. The latest World Conference on population was organized by the UNs at Cairo (Egypt) on July 11, 2012.

The net result of this family planning concept is visualized when one critically compares the average annual exponential growth rates between 1991–2001 and

2001–2011 for India. In all the States and Union Territories, the average annual exponential growth rate has reduced in 2001–2011 compared to 1991–2001 (Table 11.4).

India has also developed a much focused population policy 2020 to curb down the growth. The objective of the National Population Policy 2000 has set three objectives. One, the immediate objective, is to provide for facilities to meet the unmet needs for contraception, healthcare, infrastructure and health personnel and an integrated service delivery for basic reproductive and child healthcare. The second medium term objective is to bring the total fertility rate (TFR), i.e. the average number of children per women, in the reproductive age group, to replacement level by 2020. The third long-term objective is to achieve a stable population by 2045, a level consistent with the requirements of sustainable economic growth, social development and environmental protection.

Pointing out population growth as a major concern in India, Prime Minister Narendra Modi in his Independence Day speech on August 15, 2019, called for a deeper thought towards the issue. Apparently, the mention was an indication that the government is devising a policy or a law for curbing the population growth in country, which may also make social responsibility and stringent rules, an integral part of government family planning plans. Modi ji said that population explosion can create new problems especially for the future generations. But there is also an enlightened section of society which is aware of this challenge. We have to ponder on this issue taking along all the sections of the society.

Estimates and statistics of population in India have been showing a slightly positive picture though the country's population and remain a concern for social and economic reasons. While India's population is projected to overtake China's in less than a decade as per the United Nations 'World Population Prospects 2019' report released in June this year, the new projections for India are the lowest since the United Nations began these forecasts. The reason is the sharp decline in India's population growth rates over 10 years from 2001 to 2011. According to Census 2011, the growth rate of population has declined from 21.5% during 1991–2001 to 17.7% during 2001–2011, across all religious groups.

The population explosion has major impacts on the country ranging from health, social, environmental and economic.

In July, the government had introduced the 'Population Regulation Bill, 2019', in Rajya Sabha that calls for punitive action against people with more than two living children and making them devoid of all government services. The proposed legislation aims at disqualification from being an elected representative, denial of financial benefits and reduction in benefits under the public distribution system (PDS) for people having more than two children. The bill also suggests that government employees should give an undertaking that they will not procreate more than two children.

Public health experts are divided over the proposed 'Population Regulation Bill, 2019'. However, as a part of the disaster management arising out of population explosion, it is essential to provide food and economic security to this rising population through the lanes of alternative livelihoods as discussed in Annexure 11A.

Table 11.4 Population, percentage decadal growth and average annual exponential growth rates 1991–2001 and 2001–2011

State/UT Code	India/State/Union Territory[#]	Total population		Percentage decadal growth		Change in percentage decadal growth	Average annual exponential growth rate	
		2001	2011	1991–2001	2001–2011		1991–2001	2001–2011
1	2	3	4	5	6	7	8	9
	INDIA	**1,02,87,37,436**	**1,21,01,93,422**	**21.54**	**17.64**	**−3.9**	**1.97**	**1.64**
1	Jammu and Kashmir	1,01,43,700	1,25,48,926	29.43	23.71	−5.72	2.61	2.15
2	Himachal Pradesh	60,77,900	68,56,509	17.54	12.81	−4.73	1.63	1.21
3	Punjab	2,43,58,999	2,77,04,236	20.10	13.73	−6.37	1.85	1.3
4	Chandigarh[#]	9,00,635	10,54,686	40.28	17.1	−23.18	3.44	1.59
5	Uttarakhand	84,89,349	1,01,16,752	20.41	19.17	−1.24	1.87	1.77
6	Haryana	2,11,44,564	2,53,53,081	28.43	19.9	−8.53	2.53	1.83
7	NCT of Delhi[#]	1,38,50,507	1,67,53,235	47.02	20.96	−26.06	3.93	1.92
8	Rajasthan	5,65,07,188	6,86,21,012	28.41	21.44	−6.97	2.53	1.96
9	Uttar Pradesh	16,61,97,921	19,95,81,477	25.85	20.09	−5.76	2.33	1.85
10	Bihar	8,29,98,509	10,38,04,637	28.62	25.07	−3.55	2.55	2.26
11	Sikkim	5,40,851	6,07,688	33.06	12.36	−20.7	2.9	1.17
12	Arunachal Pradesh	10,97,968	13,82,611	27.00	25.92	−1.08	2.42	2.33
13	Nagaland	19,90,036	19,80,602	64.53	−0.47	−65	5.11	−0.05
14	Manipur	22,93,896	27,21,756	24.86	18.65	−6.21	2.25	1.72
15	Mizoram	8,88,573	10,91,014	28.82	22.78	−6.04	2.57	2.07
16	Tripura	31,99,203	36,71,032	16.03	14.75	−1.28	1.5	1.39
17	Meghalaya	23,18,822	29,64,007	30.65	27.82	−2.83	2.71	2.49
18	Assam	2,66,55,528	3,11,69,272	18.92	16.93	−1.99	1.75	1.58
19	West Bengal	8,01,76,197	9,13,47,736	17.77	13.93	−3.84	1.65	1.31
20	Jharkhand	2,69,45,829	3,29,66,238	23.36	22.34	−1.02	2.12	2.04

(continued)

Table 11.4 (continued)

State/UT Code	India/State/Union Territory#	Total population		Percentage decadal growth		Change in percentage decadal growth	Average annual exponential growth rate	
		2001	**2011**	**1991–2001**	**2001–2011**		**1991–2001**	**2001–2011**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
21	Orissa	3,68,04,660	4,19,47,358	16.25	13.97	−2.28	1.52	1.32
22	Chhattisgarh	2,08,33,803	2,55,40,196	18.27	22.59	4.32	1.69	2.06
23	Madhya Pradesh	6,03,48,023	7,25,97,565	24.26	20.3	−3.96	2.2	1.87
24	Gujarat	5,06,71,017	6,03,83,628	22.66	19.17	−3.49	2.06	1.77
25	Daman and Diu#	1,58,204	2,42,911	55.73	53.54	−2.19	4.53	4.38
26	Dadra and Nagar Haveli#	2,20,490	3,42,853	59.22	55.5	−3.72	4.76	4.51
27	Maharashtra	9,68,78,627	11,23,72,972	22.73	15.99	−6.74	2.07	1.49
28	Andhra Pradesh	7,62,10,007	8,46,65,533	14.59	11.1	−3.49	1.37	1.06
29	Karnataka	5,28,50,562	6,11,30,704	17.51	15.67	−1.84	1.63	1.47
30	Goa	13,47,668	14,57,723	15.21	8.17	−7.04	1.43	0.79
31	Lakshadweep#	60,650	64,429	17.30	6.23	−11.07	1.61	0.61
32	Kerala	3,18,41,374	3,33,87,677	9.43	4.86	−4.57	0.9	0.48
33	Tamil Nadu	6,24,05,679	7,21,38,958	11.72	15.6	3.88	1.11	1.46
34	Puducherry#	9,74,345	12,44,464	20.62	27.72	7.1	1.89	2.48
35	Andaman and Nicobar Islands#	3,56,152	3,79,944	26.90	6.68	−20.22	2.41	0.65

= Union Territory

11.4 Take Home Messages

(A) Population is a more or less a permanent aggregation of individuals of the same species inhabiting a specific geographic area at a given time. Population ecology is the study of individuals of a species constituting population regarding various factors affecting growth, distribution, natality, mortality, etc. Population of a species at a specific place is never static. It is extremely dynamic and depicts variation in its size and density with time due to influence of various abiotic and biotic factors.

(B) The accelerating pace of population growth in the last century was not due to any undue rise in birth rate of world population, but, because in the last century there was a sharp fall in death rate, advancements in healthcare control over fatal diseases such as small pox, plague and cholera and improved food distribution system (result of food security). The average number of children born to a mother has declined from 5 to 3.5 since 1950, though the size of world population has more than doubled during the same period.

(C) Population growth is the increase in number of individuals. The rate of growth is measured by an increase in the number of individuals in a population per unit time. For controlling the growth of population, natality and mortality are important factors. The percentage ratio of natality and mortality is termed vital index. Population growth is the result of interaction of biotic potential and environmental resistance. Two distinct patterns of population growth are identified, namely, S-shaped growth (Sigmoid) and J-shaped growth.

(D) The distribution of population in the world is highly non-uniform. Some areas are thickly populated while some are sparsely populated. There are various reasons behind uneven distribution of population that can be can be categorized in to geographical factors, social and cultural factors and economic factors. The geographical factors include favourable topography, availability of mineral and freshwater resources, favourable climate soil fertility and food security that invite population and help to flourish. The social and cultural factors encompass areas of better housing, education and health facilities and religious harmony. Places of religious and cultural significance also attract people, e.g. Varanasi, Jerusalem, etc. The economic factors invite population due to presence of more industries, transportation and communication facilities, employment opportunities, etc.

(E) Family planning policy has been adopted to give a check to population explosion. The net result of this family planning concept is visualized when one critically compares the average annual exponential growth rates between 1991–2001 and 2001–2011 for India. In all the States and Union Territories, the average annual exponential growth rate has reduced in 2001–2011 compared to 1991–2001. Still to sustain this rising population food security and economic security is very vital, which can be achieved through alternative livelihood.

11.5 Brain Churners

Population is a burning issue in underdeveloped and developing nations of the world. It is intricately related with industrialization and urbanization and has severe adverse effects on food security, health security and above all economic security. The readers can consider this chapter as a knowledge box on these important issues, which are threatening the mankind today. This section is a sort of '*self-appraisal approach*' as correct answers to all the questions are marked as black in the box at the end of this section.

1. Emigration may be defined as

   (a) Permanent exit of some individuals from local population
   (b) Temporary exit of some individuals from local population
   (c) Permanent entry of some individuals into local population
   (d) Temporary entry of some individuals into local population

2. Due to immigration the size of the local population

   (a) Decreases
   (b) Increases
   (c) Is not affected
   (d) None of the above

3. In population dynamics the, term migration involves

   (a) One-way movement
   (b) Exit from local population
   (c) Two-way movement
   (d) None of the above

4. Sex ratio in population study is the ratio of

   (a) Males: Females
   (b) Females: Males
   (c) Both a and b
   (d) None of the above

5. Pre-reproduction age comprises of

   (a) Adults
   (b) Old persons
   (c) Youths
   (d) Infants/adolescents

6. Triangular age pyramid in population study represents

   (a) Zero population growth
   (b) Negative population growth
   (c) Positive population growth
   (d) None of the above

7. Vital index in population growth is the percentage ratio of

   (a) Immigration and Emigration
   (b) Natality and Mortality
   (c) Migration and Immigration
   (d) Birth rate and Emigration

8. In the equilibrium phase of S-shaped population growth curve, the slope is

   (a) 0
   (b) 1
   (c) -1
   (d) $\sqrt{3}$

9. In 2050, the global population is expected to be around

   (a) 6 billion
   (b) 8 billion
   (c) 9.5 billion
   (d) 9.8 billion

10. In bell-shaped population age pyramid, the population growth is

    (a) 0
    (b) +ve
    (c) $-$ve
    (d) None of the above

11. Crash phase is a part of

    (a) S-shaped growth curve
    (b) J-shaped growth curve
    (c) Age pyramid
    (d) None of the above

12. In S-shaped growth curve the population increase during

    (a) Early or lag phase
    (b) Exponential or log phase
    (c) Diminishing phase
    (d) Stationary phase

13. Population is the permanent aggregation of individuals of

    (a) Same species
    (b) Different species
    (c) Same community
    (d) Different communities

14. Natality is defined as

    (a) Average rate of reproduction/unit time
    (b) Average rate of death/unit time
    (c) Average rate of accident/unit time
    (d) None of the above

15. The nature of population is

    (a) Static
    (b) Dynamic
    (c) Both a and b
    (d) None of the above

16. Biotic community is formed by populations of

    (a) Different species
    (b) Same species
    (c) Both a and b
    (d) None of the above

17. Population explosion is due to

    (a) High birth rate and low death rate
    (b) High death rate and low death rate
    (c) Equal death and birth rates
    (d) None of the above

18. In 2050 the least populated country in the World will be (predicted)

    (a) Nigeria
    (b) Vatican City
    (c) Indonesia
    (d) Bangladesh

19. Age ratio indicates the ratio of different age groups on the basis of

    (a) Their death
    (b) Their birth
    (c) Their ability to produce
    (d) None of the above

20. Fecundity is the

    (a) Maximum natality rate achieved under ideal condition
    (b) Minimum natality rate under ideal condition
    (c) Maximum death rate
    (d) None of the above

Answer Sheet

S. No.	a	b	c	d
1.	■			
2.		■		
3.	■			
4.		■		
5.				■
6.			■	
7.		■		
8.	■			
9.				■
10.	■			
11.		■		
12.	■			
13.	■			
14.	■			
15.		■		
16.	■			
17.	■			
18.		■		
19.			■	
20.	■			

Annexure 11A: Shrimp Feed Preparation from Seaweed

Introduction

The culture of black tiger shrimp *Penaeus monodon*, Fabricius 1798 (Crustacea: Decapoda) is practiced in the brackish water system of the Indian sub-continent with the aim to increase the fish production basically for human consumption. Feed is a significant factor in increasing the productivity and profitability in the aquaculture sector (Jamu and Ayinla 2003). From economic point of view, feed cost and feed management account for at least 60% of the production cost and appear to be

one of the major constraints against the greater expansion of aquaculture (Kaushik 1990). Present knowledge and understanding of the environmental impacts of shrimp feed among aquaculturists and nutritionists are very low and needs further refinement. Feed with animal ingredients generate wastes of complex character in the culture system. In aquatic animals, seaweeds have been used as a dietary supplement for sea bass (Valente et al. 2006), snakehead (Hashim and Mat-Saat 1992) and shrimp (Moss 1994; Peñaflorida and Golez 1996; Cruz-Suarez et al. 2000). In some instances, the inclusion of algae in feed formulations has resulted in improved performance, including improved feed efficiency, pellet quality and animal product quality. Most nutritional studies with seaweed have investigated low-dietary inclusion rates (less than 80 g/kg) to establish their possible usefulness as functional (binder effect), nutritional and nutraceutical (health protective effects) supplements (Cruz-Suarez et al. 2009). The optimum inclusion level varies depending on algae or consumer species (Peñaflorida and Golez 1996; Cruz-Suarez et al. 2000; Suarez-Garcia 2006). A lot of studies demonstrated the antioxidant properties of the algal carotenoids and the role they play in preventing much pathology linked to oxidative stress (Okuzumi et al. 1993; Yan et al. 1999). The main carotenoids in red seaweed are the β-carotene and α-carotene and their dihydroxylated derivatives, viz. zeaxanthin and lutein.

The present paper is the first-hand approach to study the effect of red seaweed (*Catenella repens*)-based formulated feed on water quality, shrimp quality and production, survival rate and FCR in a shrimp culture unit of central Indian Sundarbans. This mangrove-dominated deltaic complex is located at the apex of Bay of Bengal and has been declared as the World Heritage Site by UNESCO (1987) on account of its rich taxonomic diversity.

Materials and Methods

Experimental Design and Layout

The study area (Fig. 11.A.1) for culturing shrimp (*P. monodon*) was selected in the central part of Indian Sundarbans in Canning block located in South 24 Parganas district of the state of West Bengal (22°16′40.6″ N latitude & 88°38′18.4″ E longitude) during April to July 2009. The culture site is located on the bank of Matla River, which has an average salinity of 8.5 psu. Two ponds were selected in the study site out of which one was treated as control (C) and the other was treated as experimental (E). The cultured species (*P. monodon*) in the experimental pond was provided with the seaweed-based formulated feed, and the control pond was provided with traditional feed. Good quality shrimp seeds obtained from a local shrimp farm were stocked after proper acclimatization with ambient environmental conditions. The stocking density was 5 PL_{20}/m^2 in both the control and experimental ponds. The shrimps were fed initially at 15% of the biomass in each pond and the ration was then adjusted to actual consumption every day, thus reducing uneaten feed to a minimum.

Fig. 11.A.1 Map showing the location of culture pond at Canning, Indian Sundarbans

Water quality parameters were analysed fortnightly for a 90 days culture period (from April 15 to July 15, 2009). The parameters remained well within the optimum throughout the trial. Dissolved oxygen (D.O.), pH, transparency and nutrients were analysed following the standard spectrophotometric method (Strickland and Parsons 1968, 1972). Phytopigment concentration (Chl *a*) was analysed as per the method (Jeffrey and Humphrey 1975). Organic carbon content of pond bottom soil was estimated by the standard titration method (Walkey and Black 1934).

Formulation of Shrimp Feed and Analysis of Biochemical Constituents

Several studies have been carried out in the development of formulated feed for shrimp under controlled culture system (Mohanty et al. 1995; Mukhopadhyay and Ray 1999, 2001; Khan et al. 2004; Biswas et al. 2006). The red seaweed *C. repens* was selected as the candidate flora (source of astaxanthin) for preparation of shrimp feed. A comparative account of traditional feed (commonly used in the study area) and seaweed-based formulated feed is given (Table 11.A.1). The proximate composition of the seaweed meal was determined using the methods of Lowry for protein (Lowry et al. 1951), Soxhlet for lipid (Tecator 1983) and Anthrone method for carbohydrate (Trevelyan and Harrison 1952). Astaxanthin was estimated as per the standard spectrophotometric method (Schuep and Schierle 1995).

Zootechnical Parameters and Statistical Analysis

Individual weights and lengths of shrimps were taken at fortnightly interval for 90 days culture period and the relevant response variables were determined for each control and experimental ponds. Condition Index (C.I.) was analysed at fortnightly interval during the culture period as per the expression; **C.I.** = $W/L^3 \times 100$, where W = weight of the cultured species (in gm) and L = length of the cultured species (in cm). Percentage weight gain was calculated as the difference in weight from the average final weight with respect to the initial weight; weight gain = [(average individual final weight – average individual initial weight)/average individual initial weight] × 100. Feed consumption reported was the total of the consumption estimated for 90 days period. The survival rate was measured as percentage of the difference of stocking number and production volume (No.) at the end of the culture period. Feed Conversion Ratio (FCR) was analysed after the harvesting of shrimps as per the expression: FCR = $\Delta f/\Delta b$, where, Δf = Change in feed biomass and Δb = Change in body biomass of the cultured species.

Table 11.A.1 Comparative analysis of shrimp feed components

Traditional shrimp feed	Percentage (%)	Specially formulated shrimp feed	Percentage (%)
Trash shrimp dust	20	Soybean oil cake	40
Dry fish dust	30		
Soybean oil cake	10		
Rice bran	12.5	Rice bran	15
Flour	7	Wheat bran	15
Groundnut dust	5	Mustard oil cake	12.5
Maize dust	4.5		
Coconut Khail	10	Coconut oil cake	12.5
Vitamins and minerals mixture	1.0	*Catenella repens* (as a source of carotenoid)	5

Body pigmentation was assessed for each treatment on shrimp cooked for 5 min in boiling water and comparing the orange-red colouration with Roche SalmoFan™ colour score. Analysis of variance (ANOVA) was computed between all the selected parameters (indicators of our experiment) considering both control and experimental ponds to evaluate the differences caused by inclusion of seaweed in the feed.

Results

Biochemical Composition of Seaweeds and Specially Formulated Feed

The biochemical composition of *C. repens* showed protein ranges between 4.01 ± 1.28% and 15.97 ± 1.17%; lipid ranges between 0.17 ± 0.02% and 0.24 ± 0.01%; carbohydrate values between 21.52 ± 1.87% and 35.74 ± 1.55% and astaxanthin values between 87.91 ± 2.67 ppm and 188.34 ± 2.89 ppm (Banejee et al. 2009). The seaweed was used as an ingredient (5%) of specially formulated feed. The proximate composition of traditional and seaweed-based formulated feed is highlighted (Table 11.A.2). Traditional feed showed higher protein, lipid and carbohydrate values than seaweed-based feed. However, astaxanthin content was almost nil in traditional feed.

Shrimp Growth and Pigmentation

Shrimps fed with *Catenella* diet exhibited higher final weights and better weight gain (Table 11.A.3) at the end of the experiment (25.5 gm final weight and 2450% weight gain) in comparison to control pond (20 gm final weight and 1900% weight gain). C.I. values of shrimp were also higher in experimental ponds (3.41 ± 4.68) than control pond (3.08 ± 4.52) (Table 11.A.3 and Fig. 11.A.2). The FCR value for control pond was 1.45 and for experimental pond was 1.39. The survival rate was found to be 55% in the control pond and 70% in experimental pond. The production volume was also maximum in case of experimental pond (69.97 kg) compared to control pond (20.10 kg) as given (Table 11.A.4). The present pilot scale study speaks in favour of healthy pond environment, better growth, higher survival rate and low FCR values through use of seaweed-based feed.

Table 11.A.2 Proximate composition of the traditional and formulated feed

Parameters	Traditional feed	Formulated feed
Protein (%)	32 ± 2.65	28.29 ± 0.58
Lipid (%)	4.7 ± 2.05	1.62 ± 0.03
Carbohydrate (%)	22.1 ± 4.08	17.25 ± 0.50
Astaxanthin (ppm)	BDL	62.33 ± 2.78

Values are the mean ± SD

Table 11.A.3 Zootechnical parameters recorded in the culture ponds

Parameters	Control pond	Experimental pond
Condition index of shrimp	3.08 ± 4.52*	3.41 ± 4.68*
% weight gain	1900	2450
Astaxanthin in shrimp (ppm)	9.52 ± 5.45*	11.32 ± 6.37*
Roche SalmoFan™ colour score	24	29
Survival rate (%)	55	70
Δ F	27.67	72.65
Δ B	19.09	52.14
FCR	1.45	1.39

*Values are the mean ± SD

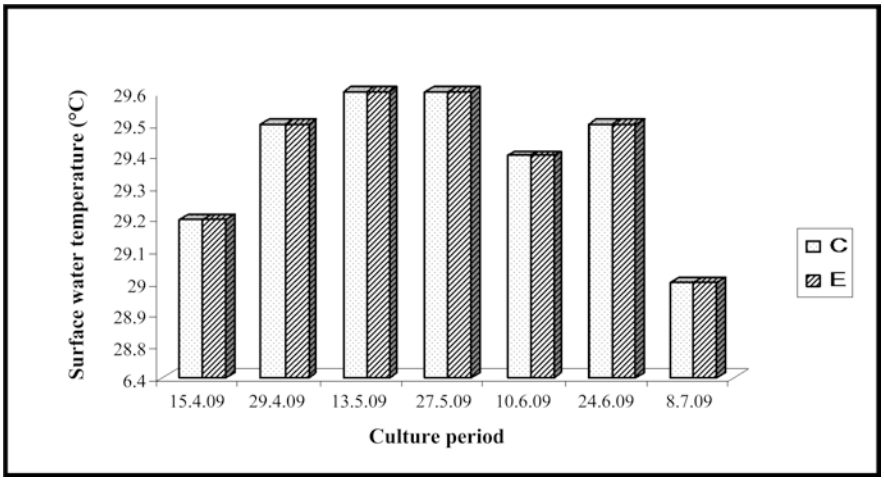

Fig. 11.A.2 Fortnightly variations of condition index of cultured shrimp from control (C) and experimental (E) ponds

An important factor governing the consumer acceptance and market value of many cultivated fish and shrimp species is the pink or red colouration of their flesh or boiled exoskeleton (Brun and Vidal 2006). In the wild, this colouration is achieved through the ingestion of carotenoid pigments particularly astaxanthin contained within invertebrate food organisms (Johnson et al. 1977; Ibrahim et al. 1984). The *Catenella*-based feed in the present study resulted in higher astaxanthin values in shrimps of experimental pond (11.32 ± 6.37 ppm) as reflected through darker orange-red colouration of shrimp exoskeleton in comparison to control pond (9.52 ± 5.45 ppm). Roche SalmoFan™ colour score showed the value of 24 in control pond, much lesser than experimental pond with a colour score of 29 (Table 11.A.3 and Fig. 11.A.3).

Table 11.A.4 Cost-benefit analysis of the culture ponds

	Items	Control pond	Experimental pond
Cost	Area (m^2)	365.40	784.08
	Stocking density @ 5 PL/ m^2	1827	3920
	Seed cost (in Rs.)	913.50	1960.00
	Feed given (in kg)	29.93	78.82
	Feed cost (in Rs.)	@ Rs. 35/– per kg = 1047.55	@ Rs. 19 per kg (excluding the cost of *C. repens*) = 1497.58
	Labour cost (supported by beneficiary himself)	Nil	Nil
	Experimental cost (in Rs.)	5000	5000
	Total cost (in Rs.)	6961.05	8457.58
	Total unit cost (in Rs./ m^2)	**19.05**	**10.79**
Benefit	Production (in kg)	@ 20 gm/ kg = 20.10	@ 25.5 gm/kg =69.97
	Return @ Rs. 350/kg	7035.00	24,489.50
	Expenditure (in Rs.)	6961.05	8457.58
	Total profit/pond (in Rs.)	73.95	16,031.92
	Profit/unit area (in Rs./ m^2)	**0.20**	**20.45**

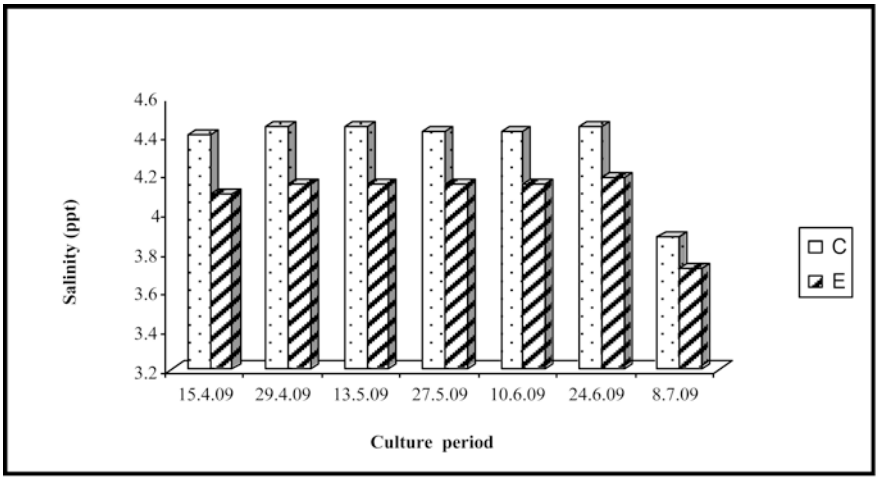

Fig. 11.A.3 Fortnightly variations of astaxanthin content of cultured shrimp from control (C) and experimental (E) ponds

Variation in Environmental Parameters

The surface water temperature during the study period ranged from 29.0 °C to 29.6 °C with a mean value of 29.4 ± 0.22 °C in both the culture ponds (Table 11.A.5 and Fig. 11.A.4). The surface water salinity ranged from 3.72 psu to 4.45 psu with

Table 11.A.5 Variation in the physico-chemical parameters of the culture ponds

Parameters	Control pond	Experimental pond
Surface water temperature (°C)	29.4 ± 0.22	29.4 ± 0.22
Surface water salinity (psu)	4.35 ± 0.2	4.08 ± 0.16
pH	7.88 ± 0.35	8.08 ± 0.03
Transparency (cm)	17.02 ± 2.02	24.3 ± 2.58
Dissolved oxygen (mgl^{-1})	4.66 ± 0.77	5.47 ± 0.12
Nitrate ($\mu gatl^{-1}$)	19.5 ± 1.21	16.6 ± 1.01
Phosphate ($\mu gatl^{-1}$)	2.22 ± 0.05	2.0 ± 0.29
Silicate ($\mu gatl^{-1}$)	64.01 ± 2.23	63.32 ± 2.67
Chlorophyll *a* (mgm^{-3})	1.74 ± 0.51	1.92 ± 0.16
Soil organic carbon (%)	1.18 ± 0.16	1.07 ± 0.1

Values are the mean ± SD

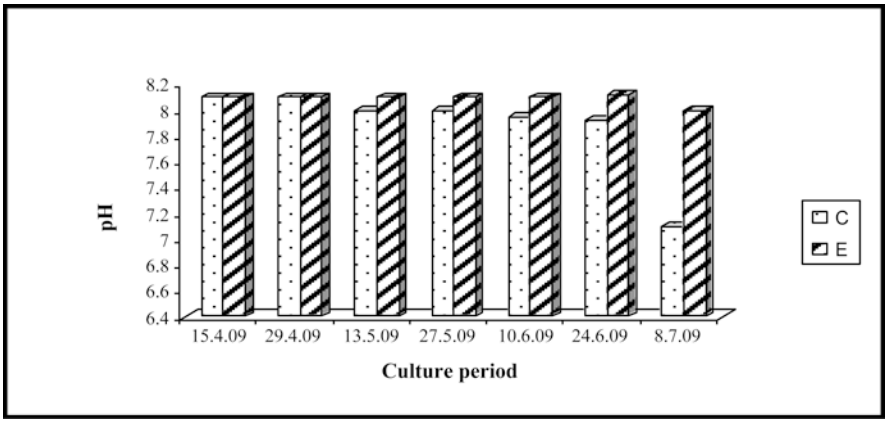

Fig. 11.A.4 Fortnightly variations of surface water temperature in control (C) and experimental (E) ponds

a mean value of 4.35 ± 0.2 psu in the control pond and 4.08 ± 0.16 psu in the experimental pond (Table 11.A.5 and Fig. 11.A.5). The surface water pH ranged from 7.10 to 8.12 with a mean value of 7.88 ± 0.35 in the control pond and 8.08 ± 0.03 in the experimental pond (Table 11.A.5 and Fig. 11.A.6). The D.O. values ranged from 3.08 mg l^{-1} to 5.58 mg l^{-1} with a mean value of 4.66 ± 0.77 mg l^{-1} in the control pond and 5.47 ± 0.12 mg l^{-1} in the experimental pond (Table 11.A.5 and Fig. 11.A.7). The water transparency during the study period ranged from 14.35 cm to 27.5 cm with a mean value of 17.02 ± 2.02 cm in the control pond and 24.3 ± 2.58 cm in the experimental pond (Table 11.A.5 and Fig. 11.A.8). The nutrient values (nitrate, phosphate and silicate) ranged from 15.12 µgat l^{-1} to 21.33 µgat l^{-1} with a mean

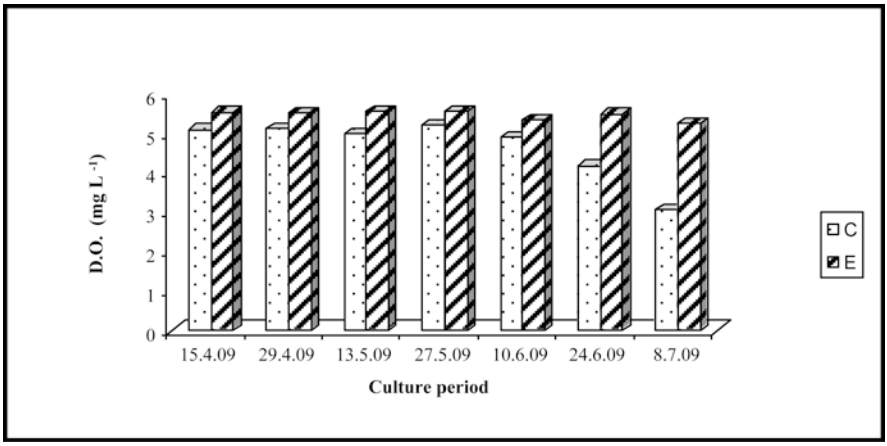

Fig. 11.A.5 Fortnightly variations of surface water salinity in control (C) and experimental (E) ponds

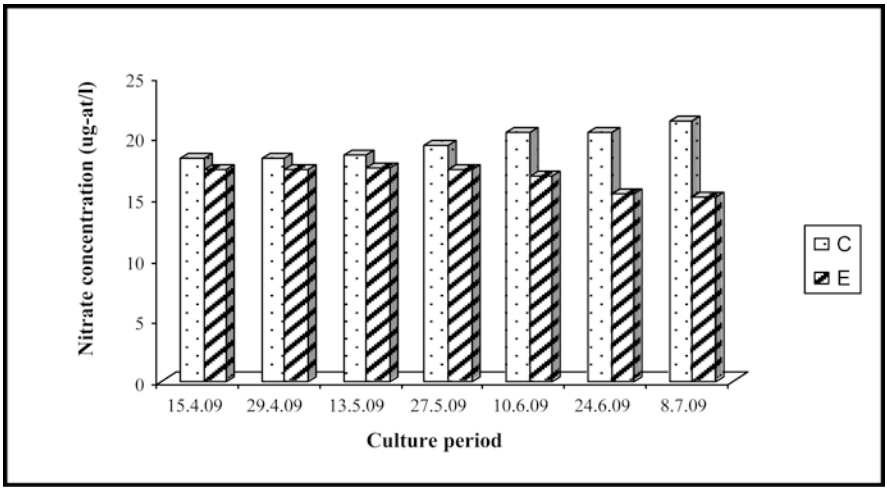

Fig. 11.A.6 Fortnightly variations of surface water pH in control (C) and experimental (E) ponds

value of 19.5 ± 1.21 µgat l^{-1} in the control pond and 16.6 ± 1.01 µgat l^{-1} in the experimental pond (Table 11.A.5 and Fig. 11.A.9) for nitrate, from 1.53 µgatl^{-1} to 2.28 µgatl^{-1} with a mean value of 2.22 ± 0.05 µgatl^{-1} in the control pond and 2.0 ± 0.29 µgatl^{-1} in the experimental pond (Table 11.A.5 and Fig. 11.A.10) for phosphate and from 59.63 µgatl^{-1} to 66.2 µgatl^{-1} with a mean value of 64.01 ± 2.23 µgatl^{-1} in the control pond and 63.32 ± 2.67 µgatl^{-1} in the experimental pond

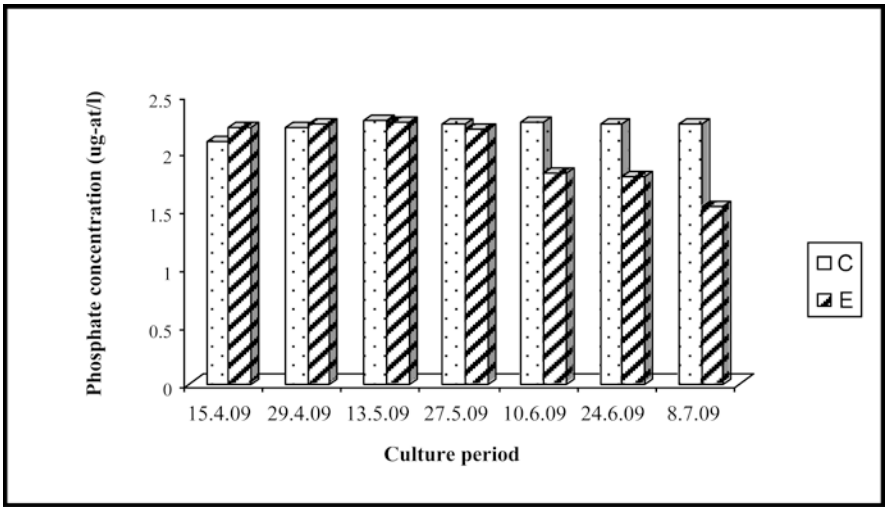

Fig. 11.A.7 Fortnightly variations of surface water dissolved oxygen in control (C) and experimental (E) ponds

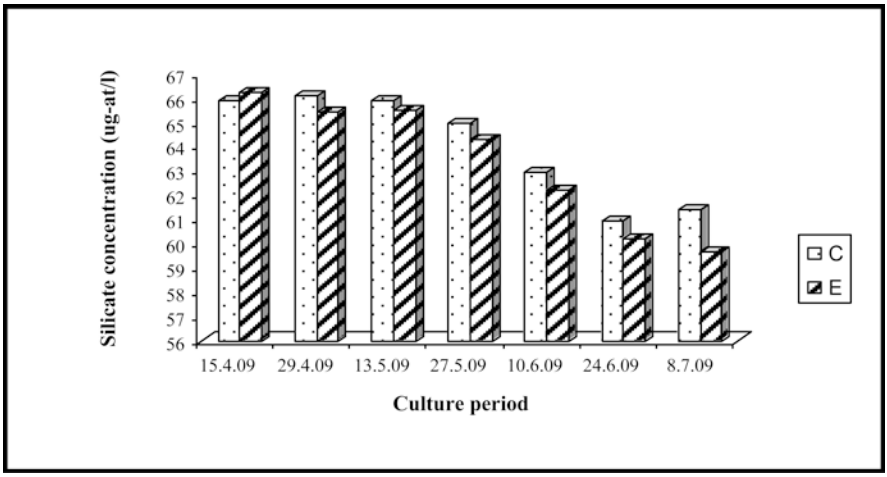

Fig. 11.A.8 Fortnightly variations of surface water transparency in control (C) and experimental (E) ponds

(Table 11.A.5 and Fig. 11.A.11) for silicate. The Chl *a* concentration during the study period ranged from 0.97 mg m^{-3} to 2.66 mg m^{-3} with a mean value of 1.74 ± 0.51 mg m^{-3} in the control pond and 1.92 ± 0.16 mg m^{-3} in the experimental pond (Table 11.A.5 and Fig. 11.A.12). The organic carbon of the pond bottom soil

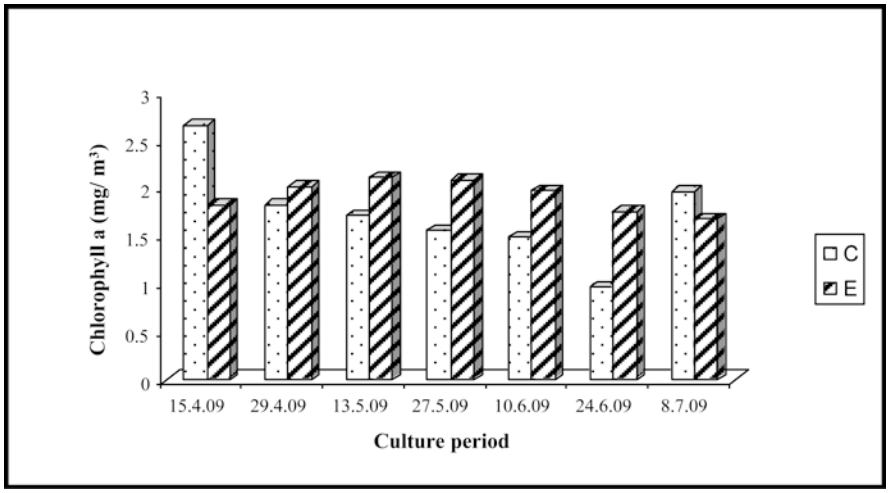

Fig. 11.A.9 Fortnightly variations of nitrate concentration in control (C) and experimental (E) ponds

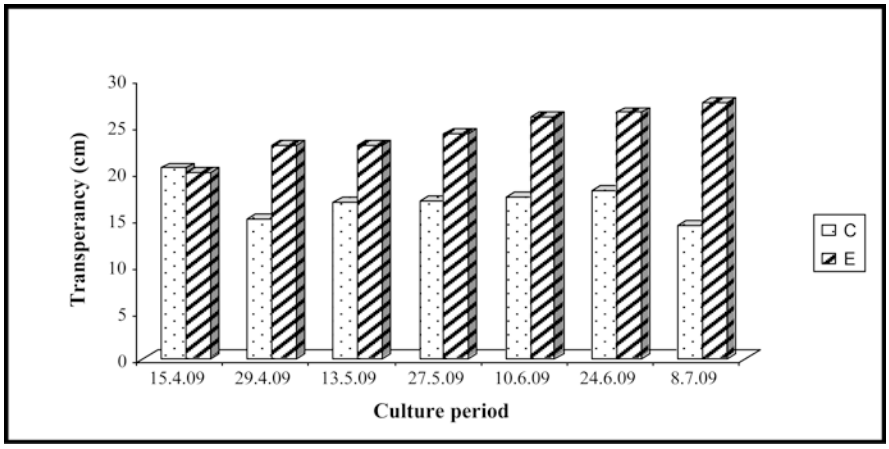

Fig. 11.A.10 Fortnightly variations of phosphate concentration in control (C) and experimental (E) ponds

during the study period ranged from 0.97% to 1.35% with a mean value of 1.18 ± 0.16% in the control pond and 1.07 ± 0.10% in the experimental pond (Table 11.A.5 and Fig. 11.A.13).

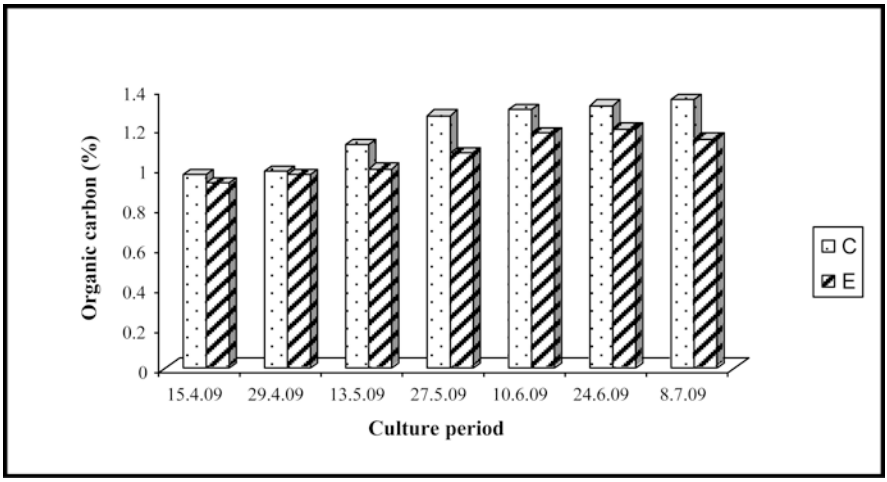

Fig. 11.A.11 Fortnightly variations of silicate concentration in control (C) and experimental (E) ponds

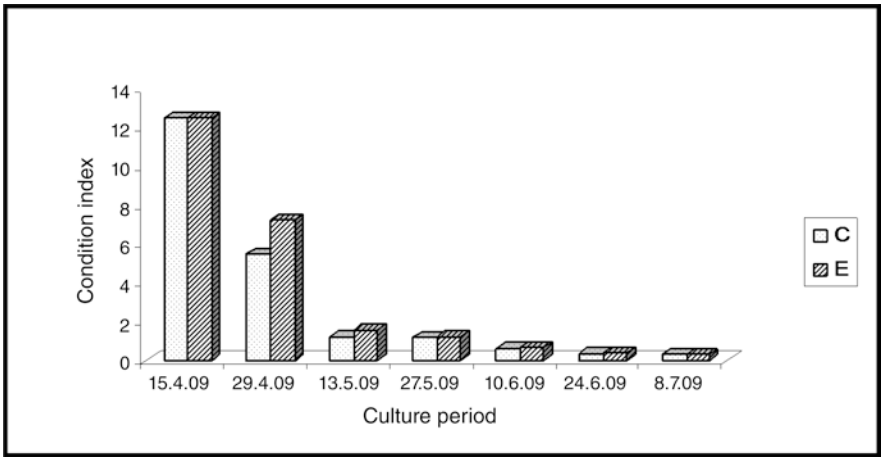

Fig. 11.A.12 Fortnightly variations of chlorophyll *a* in control (C) and experimental (E) ponds

Discussion

Feed Quality

Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient through feed both in terms of quality and quantity, irrespective of the culture system in which they are grown (Kader et al.

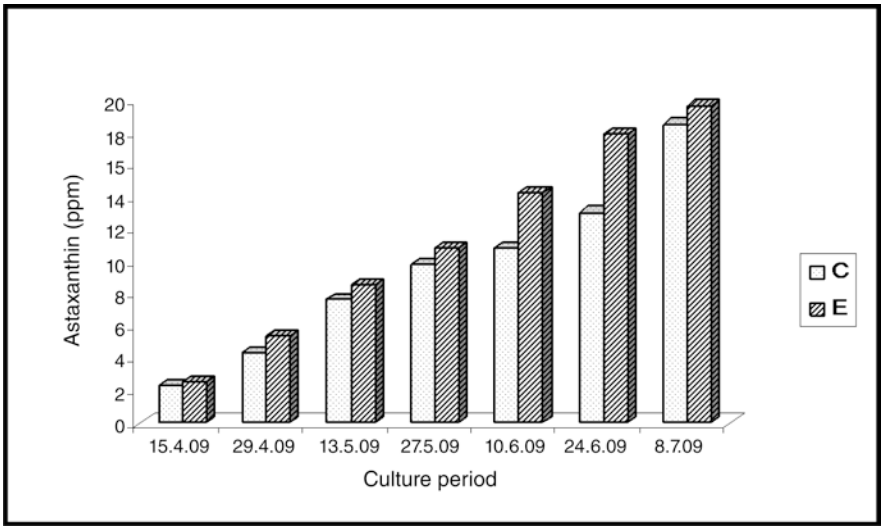

Fig. 11.A.13 Fortnightly variations of organic carbon in control (C) and experimental (E) ponds

2005). Therefore, supply of inputs (feeds, fertilizers etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved (Hasan 2001). The nutrient balance of feed influences feed utilization and growth of fish. It is very essential to know the nutritional requirements particularly for protein, lipid and energy for optimum growth of fish species as well as in formulating a balanced diet. Dietary protein and energy levels are known to influence the growth and body composition of fish (Lovell 1989). Improper protein and energy levels in feed increase fish production cost and deteriorates water quality. Insufficient energy in diets causes protein waste due to the increase proportion of dietary protein used for energy and the produced ammonia can reduce the water quality (Phillips 1972; Prather and Lovell 1973; Shyong et al. 1998). On the contrary, excessive energy in diets can lead to increased body lipid deposition and growth reduction because of lack of necessary nutrient for growth (Daniels and Robinson 1986; Van der Meer et al. 1997). This is often the case seen in case of traditional meal which has resulted in deterioration of water quality parameters in the control pond (Table 11.A.5). In the present study, the specially formulated feed prepared from *C. repens* had optimum protein, lipid, carbohydrate and astaxanthin content and the values were also within the recommended nutrient levels for fish (National Research Council 1983).

Protein is the major growth promoting factor in feed. The protein requirement of fish are influenced by various factors such as fish size, water temperature, feeding rate, availability and quality of natural foods and overall digestible energy content of diet (Satoh 2000; Wilson 2000). In the present study, protein level in formulated feed was found to be 28.29 ± 0.58% in comparison to 32 ± 2.65% in traditional feed. Lipids are primarily included in formulated diet to maximize their protein sparing effect (Hasan

2001) by being a source of energy. Low lipid content of the specially formulated feed results in greater binding efficiency and more pellet water stability. Lipid values were found to be lower in specially formulated feed indicating the efficiency of the present feed in maintaining water stability. Carbohydrate levels in feed are the most suitable sources of energy for shrimps. The best carbohydrate sources of shrimp feed are those derived from low-cost practical ingredients (e.g. wheat flour, rice bran, etc.). The formulated feed in the present study also supports the above view (Tables 11.A.1 and 11.A.3). Use of *C. repens* as astaxanthin supplement (source of carotenoid) has increased the antioxidative property of the feed and resulted in higher pigment concentration in shrimp species of experimental pond (Tables 11.A.3 and 11.A.2).

Growth Performance of Shrimp

The present case study exhibited significant weight gain in experimental pond compared to control pond ($p < 0.05$). The significant variation of C.I. with time is due to the growth in biomass with the passage of time. Feeding the shrimps (*P. monodon*) supplemented with *Catenella* meal resulted in better growth and survival rate in the present programme. The percentage increase in biomass was also higher in experimental pond than control pond (Table 11.A.3). This was also revealed by the low FCR values for experimental pond than control pond, which proves the acceptance of the specially formulated feed by the shrimp species. Cost-benefit analysis (CBA) has also confirmed higher profit percentage (Table 11.A.4).

Pigmentation

Colour development depends on the carotenoid content of the feed (Moretti et al. 2006) although it has been reported that dietary carotenoids are responsible for less than 20% of the flesh pigmentation in aquatic organisms (Torrisen et al. 1989; Storebakken and No 1992). Carotenoid pigmentation is affected by dietary pigment source, dosage level, duration of feeding, dietary composition, degree of carotenoid esterification, etc. (Meyers and Latscha 1997; Bjerkeng 2000; Buttle et al. 2001; Gomes et al. 2002; White et al. 2002). Animals including fish and shrimp are unable to synthesize carotenoids, but certain aquaculture species (i.e. crustaceans, omnivorous/herbivorous fish) are capable of transforming ingested carotenoids such as $\propto -$ carotene and depositing the resulting end products, usually astaxanthin in their tissues (Simpson and Chichester 1981; NRC 1983). ANOVA results showed a significant variation of astaxanthin between the control and experimental ponds ($p < 0.05$) which may be attributed to astaxanthin level in feed types. The seaweed-based feed had an astaxanthin of 62.33 ± 2.78 ppm, whereas the astaxanthin level in traditional feed was BDL. Red seaweed *C. repens* is a rich source of carotenoid (Chakraborty and Santra 2008; Banejee et al. 2009) and hence may be the cause for high astaxanthin level in the species of experimental pond. Pigmentation of muscle is a major quality attributed for shrimps (Brun and Vidal 2006; Darachai et al. 1998).

Coloration of muscles in shrimps using seaweed such as *C. repens* as a natural pigment source may enhance the potential of seaweed inclusion in shrimp feed and may perhaps replace or reduce artificial colourants currently used by the industry (Banerjee 2009; Nickell and Bromage 1998).

Water Quality of the Cultured Ponds

Aquatic parameters of the shrimp culture ponds is a reflection of the quality of feed provided to the cultured species, and the condition index values symbolize the suitability of the environment for the species (Maciena and Murphey 1988). Surface water temperature in both the culture ponds showed more or less parallel trend of variation throughout the study period. This is reflected in the ANOVA results which showed no significant variation of the parameter between the control and experimental ponds as well as between the culture periods. The uniformity in temperature profile is due to the location of both the ponds in the same site that experience similar weather and climate. Water temperature plays a major role in shrimp enzyme kinetics which may have a regulatory influence on their growth (Mitra et al. 2006). It also affects the process of moulting during the post larval stage of shrimps (WWF-India 2006). In the present study, no significant relationship was observed between condition index of shrimp and surface water temperature.

The salinity of the Hugli-Matla estuarine complex is known to exhibit intensive variations (Saha et al. Saha et al. 1995). The selected station, Canning is located in the Matla estuarine stretch, which is known for its dynamics in tidal condition. ANOVA results showed significant spatial (between ponds) and temporal (between months) variation of salinity ($p < 0.05$). The relatively higher C.I. values in the experimental pond with less salinity (4.08 ± 0.16 psu) prove the efficiency of formulated feed in combating the stress posed by salinity which in turns increases the astaxanthin level in the cultured species (Kobayashi et al. 1992; Tjahjono et al. 1994; Harker et al. 1996; Boussiba 2000; Sarada et al. 2002). Shrimp culture directly affects the pH of the pond bottom through deposition of excess feed, shrimp excreta, dead shrimps, etc. These shift the soil and overlying aquatic pH towards acidic condition. In the present study, such condition was not observed at culture site owing to the traditional practice of liming at a regular interval of time in the lower Gangetic region. ANOVA result also confirmed the above view as no significant variations of pH between the ponds was observed. High organic carbon load was observed in the control pond due to use of traditional feed resulting in low pH. ANOVA result shows significant variation of organic carbon content between the ponds ($p < 0.05$). D.O. is a vital parameter regulating the aquatic life. The shrimp health is a direct function of dissolved oxygen and its diurnal variation. Excessive organic load in the system results in lowering the D.O. value posing threat to the survival of aquatic life. In the present study, the D.O. level in the control pond showed lower value owing to deposition of organic carbon at the bottom of the pond. ANOVA result confirmed the significant variation of D.O. between the ponds. Transparency controls the phytoplankton standing stock in shrimp culture ponds due to their dependency on the

solar radiation for photosynthesis. This parameter has thus a major role in regulating the phytopigment level and coloration of shrimp pond water. The formulated feed provided in the experimental pond showed increased transparency of the water due to its unique binding property. This upgraded the water quality as reflected by the high-condition index values of the shrimps in the experimental pond. The above statement was confirmed by ANOVA results which showed significant variation of transparency between the ponds ($p < 0.05$). The ready acceptance of the seaweed-based feed by the cultured species in the experimental pond may be the basis of reduced suspended particulate matter in aquatic phase that caused variation in water transparency.

Nutrients comprising of nitrate, phosphate and silicate in the aquatic phase of the culture ponds are generated through the excretory products of the cultured species, left over feed and also by the churning of the pond bed (due to runoff from the adjacent land masses). ANOVA results showed significant variation of nitrate between the ponds ($p < 0.05$) which may be due to the leaching of the feed ingredients (particularly from animal component in traditional feed) in pond water and also the faecal matter that generates ammonia (Mitra and Choudhury 1995). ANOVA results for the phosphate concentration during the study period showed no significant variation between the ponds. For silicate the variation between the ponds was significant ($p < 0.05$) which may be attributed to difference in bed materials of the ponds. Phytopigment (Chl *a*) are indicators of aquatic productivity and standing stock of phytoplankton. Although higher concentration of phytopigment signify eutrophic condition of water, but their presence in optimum level is healthy for shrimp growth as the phytoplankton constitute the natural diet of shrimp. In the present study, an optimum Chl *a* concentration and lower nutrient values in the experimental pond proves the effective utilization of nutrients by aquatic phytoplankton. ANOVA results showed no significant variation of Chl *a* between the ponds as well as between the culture periods, implying healthy growth of the cultured species.

Aquaculture has become a peak industry in the present millennium, which involves seafood farming with shrimp, cuttlefish, squid, lobster and other such culinary delights actually 'cultivated' in aquatic enclosures under scientifically controlled conditions (Rajkhowa 2005). The use of nutrient-rich feed continues to gain wide acceptance in the aquaculture industry in order to boost up the quality of the aquacultural products. The use of quality feed results in substantial reduction in the overall variable cost of an operation through improved animal performance, better FCR and improved water quality due to a reduction in the amount of nutrients and solids (i.e. faeces and uneaten food) in the waste water effluent. *C. repens*-based formulated feed showed better growth performance of the cultured species with respect to condition index values and survival rate. Body pigmentation improved in the cultured species of experimental pond and showed significantly higher astaxanthin level than the controlled pond. cost-benefit analysis (CBA) reflects high profitability of using floral-based feed instead of the traditional feed. A series of experiments are still needed for time testing the results and make the programme sustainable for the poor island dwellers of lower Gangetic delta.

Annexure 11B: Countries, Territories or Areas with Reported Laboratory-Confirmed COVID-19 Cases and Deaths; Data as of 19 March 2020

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Western Pacific region					
China	81,174	58	3242	11	Local transmission
Republic of Korea	8413	93	84	3	Local transmission
Japan	873	44	29	1	Local transmission
Malaysia	673	120	2	2	Local transmission
Australia	510	96	6	1	Local transmission
Singapore	313	47	0	0	Local transmission
Philippines	187	0	14	2	Local transmission
Viet Nam	66	5	0	0	Local transmission
Brunei Darussalam	56	2	0	0	Local transmission
Cambodia	35	11	0	0	Local transmission
New Zealand	20	9	0	0	Local transmission
Mongolia	5	1	0	0	Imported cases only
Territories					
Guam	5	2	0	0	Local transmission
French Polynesia	3	0	0	0	Imported cases only
European region					
Italy	35,713	4207	2978	473	Local transmission
Spain	13,716	2538	598	107	Local transmission
France	9043	0	244	0	Local transmission
Germany	8198	1042	13	0	Local transmission

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Switzerland	3010	353	21	2	Local transmission
The United Kingdom	2630	672	103	0	Local transmission
Netherlands	2051	0	58	0	Local transmission
Austria	1646	314	4	1	Local transmission
Belgium	1486	0	14	0	Local transmission
Norway	1423	115	3	0	Local transmission
Sweden	1279	112	3	0	Local transmission
Denmark	1044	67	4	0	Local transmission
Portugal	642	194	2	1	Local transmission
Czechia	522	30	0	0	Local transmission
Israel	427	0	0	0	Local transmission
Greece	418	0	5	0	Local transmission
Finland	359	40	0	0	Local transmission
Ireland	292	0	2	0	Local transmission
Poland	287	0	5	0	Local transmission
Slovenia	286	0	1	0	Local transmission
Estonia	258	33	0	0	Local transmission
Iceland	250	25	0	0	Local transmission
Romania	246	62	0	0	Local transmission
Luxembourg	210	63	2	1	Local transmission
Turkey	191	51	2	1	Local transmission
Russian Federation	147	54	0	0	Imported cases only
San Marino	109	5	14	3	Local transmission

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Slovakia	105	8	0	0	Local transmission
Serbia	96	11	0	0	Local transmission
Bulgaria	92	11	2	0	Local transmission
Armenia	84	32	0	0	Local transmission
Croatia	81	16	0	0	Local transmission
Latvia	71	11	0	0	Imported cases only
Albania	59	2	2	1	Local transmission
Cyprus	58	25	0	0	Local transmission
Hungary	58	8	1	0	Local transmission
Malta	48	10	0	0	Imported cases only
Belarus	46	10	0	0	Local transmission
Georgia	38	4	0	0	Imported cases only
Bosnia and	36	7	0	0	Local transmission
Herzegovina					
Kazakhstan	36	3	0	0	Imported cases only
North Macedonia	36	5	0	0	Local transmission
Republic of Moldova	36	0	0	0	Local transmission
Azerbaijan	34	13	1	1	Imported cases only
Lithuania	26	1	0	0	Imported cases only
Liechtenstein	25	18	0	0	Imported cases only
Ukraine	16	7	2	0	Local transmission
Uzbekistan	16	0	0	0	Imported cases only
Monaco	9	0	0	0	Under investigation

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Kyrgyzstan	3	3	0	0	Under investigation
Montenegro	2	0	0	0	Imported cases only
Holy See	1	0	0	0	Under investigation
Territories					
Faroe Islands	58	11	0	0	Imported cases only
Andorra	39	23	0	0	Imported cases only
Gibraltar	8	5	0	0	Under investigation
Jersey	5	0	0	0	Imported cases only
Greenland	2	0	0	0	Under investigation
Guernsey	1	0	0	0	Imported cases only
Southeast Asia region					
Indonesia	227	55	19	14	Local transmission
Thailand	212	35	1	0	Local transmission
India	151	14	3	0	Local transmission
Sri Lanka	42	13	0	0	Local transmission
Maldives	13	0	0	0	Local transmission
Bangladesh	10	2	0	0	Local transmission
Bhutan	1	0	0	0	Imported cases only
Nepal	1	0	0	0	Imported cases only
Eastern Mediterranean region					
Iran	17,361	1192	1135	147	Local transmission
Qatar	442	0	0	0	Local transmission
Bahrain	256	5	1	0	Local transmission
Pakistan	241	54	0	0	Imported cases only

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Saudi Arabia	238	67	0	0	Local transmission
Egypt	196	30	6	2	Local transmission
Iraq	164	0	12	0	Local transmission
Kuwait	142	12	0	0	Local transmission
Lebanon	133	13	4	1	Local transmission
United Arab Emirates	113	15	0	0	Local transmission
Jordan	52	13	0	0	Imported cases only
Morocco	49	11	2	0	Local transmission
Oman	33	9	0	0	Imported cases only
Tunisia	29	5	0	0	Local transmission
Afghanistan	22	0	0	0	Imported cases only
Djibouti	1	1	0	0	Under investigation
Somalia	1	0	0	0	Imported cases only
Sudan	1	0	1	0	Imported cases only
Territories					
occupied Palestinian territory	44	3	0	0	Local transmission
Region of the Americas					
United States of	7087	3551	100	42	Local transmission
America					
Canada	569	145	8	7	Local transmission
Brazil	291	57	1	1	Local transmission
Chile	238	82	0	0	Local transmission
Ecuador	155	97	2	0	Local transmission
Peru	145	59	0	0	Local transmission

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Colombia	93	48	0	0	Local transmission
Mexico	93	11	0	0	Imported cases only
Panama	86	17	1	0	Local transmission
Argentina	79	14	2	0	Local transmission
Costa Rica	50	9	0	0	Local transmission
Venezuela	36	3	0	0	Imported cases only
Uruguay	29	23	0	0	Imported cases only
Dominican Republic	21	0	1	0	Local transmission
Jamaica	13	1	0	0	Local transmission
Bolivia	12	1	0	0	Imported cases only
Paraguay	11	2	0	0	Local transmission
Cuba	10	5	1	0	Local transmission
Honduras	9	1	0	0	Imported cases only
Trinidad and Tobago	7	2	0	0	Imported cases only
Guatemala	6	0	1	0	Imported cases only
Guyana	4	1	1	0	Local transmission
Bahamas	3	2	0	0	Local transmission
Barbados	2	2	0	0	Imported cases only
Saint Lucia	2	0	0	0	Imported cases only
Antigua and Barbuda	1	0	0	0	Imported cases only
Montserrat	1	1	0	0	Imported cases only
Saint Vincent and the Grenadines	1	0	0	0	Imported cases only
Suriname	1	0	0	0	Imported cases only

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Territories					
Guadeloupe	33	15	0	0	Imported cases only
Martinique	23	7	0	0	Imported cases only
French Guiana	11	4	0	0	Imported cases only
Puerto Rico	5	2	0	0	Imported cases only
Aruba	4	2	0	0	Imported cases only
Saint Martin	4	2	0	0	Under investigation
Curaçao	3	0	0	0	Imported cases only
Saint Barthélemy	3	0	0	0	Under investigation
United States Virgin Islands	2	0	0	0	Imported cases only
Cayman Islands	1	0	1	0	Imported cases only
African region					
South Africa	116	54	0	0	Local transmission
Algeria	72	12	6	2	Local transmission
Senegal	36	9	0	0	Local transmission
Burkina Faso	26	6	1	1	Imported cases only
Rwanda	11	4	0	0	Local transmission
Cameroon	10	5	0	0	Local transmission
Cote d'Ivoire	9	3	0	0	Imported cases only
Ghana	9	1	0	0	Imported cases only
Nigeria	8	6	0	0	Imported cases only
Democratic Republic of the Congo	7	4	0	0	Local transmission
Kenya	7	4	0	0	Local transmission

(continued)

Reporting country/ territory/area	Total confirmed cases	Total confirmed new cases	Total deaths	Total new deaths	Transmission classification
Ethiopia	6	1	0	0	Imported cases only
Seychelles	6	2	0	0	Imported cases only
Congo	3	2	0	0	Imported cases only
Equatorial Guinea	3	2	0	0	Imported cases only
Gabon	3	2	0	0	Imported cases only
Mauritius	3	3	0	0	Under investigation
United Republic of Tanzania	3	2	0	0	Imported cases only
Liberia	2	1	0	0	Local transmission
Mauritania	2	1	0	0	Imported cases only
Namibia	2	0	0	0	Imported cases only
Zambia	2	2	0	0	Imported cases only
Benin	1	0	0	0	Imported cases only
Central African Republic	1	0	0	0	Imported cases only
Eswatini	1	0	0	0	Imported cases only
Gambia	1	1	0	0	Imported cases only
Guinea	1	0	0	0	Imported cases only
Togo	1	0	0	0	Imported cases only
Territories					
Réunion	12	3	0	0	Imported cases only
Mayotte	3	2	0	0	Imported cases only
Subtotal for all regions	**209,127**	**16,556**	**8771**	**828**	
International conveyance (Diamond Princess)	712	0	7	0	Local transmission
Grand total	**209,839**	**16,556**	**8778**	**828**	

Case classifications are based on WHO case definitions for COVID-19
Source: https://www.worldometers.info/coronavirus/

References

Banerjee K (2009) Income generation through eco-friendly pisciculture in Indian Sundarbans: an innovative approach towards sustainable green technology. Report of WOS-B Scheme, Department of Science and Technology, Government of India, pp 1–20

Banejee K, Ghosh R, Homechaudhuri S, Mitra A (2009) Seasonal variation in the biochemical composition of red seaweed (*Catenella repens*) from Gangetic delta, northeast coast of India. J Earth Syst Sci 118(5):1–10. Springer-Verlag

Biswas G, Jena JK, Singh SK, Patmajhi P, Muduli HK (2006) Effect of feeding frequency on growth, survival and feed utilization in mrigal, *Cirrhinus mrigala* and rohu, *Labeo rohita* during nursery rearing. Aquaculture 254:211–218

Bjerkeng B (2000) Carotenoid pigmentation in salmonid fishes – recent progress. In: Cruz-Suarez LE, Ricque-Marie D, Tapia-Salazar M, Olvera-Novoa MA, Cerecedo-Olvera R (eds) Avances en Nutricion Acuicola V – Memorias del Quinto Simposium Internacional de Nutricion Acuícola, Merida, Mexico, 19–22 Noviembre 2000, vol 5. Universidad Autonoma de Nuevo Leon, Monterrey, pp 71–89. ISBN 970-694-52-9

Boussiba S (2000) Carotenogenesis in the green algae *Haematococcus pluvialis*: Cellular physiology and stress response. Plant Physiol 108:111–117

Brun HL, Vidal F (2006) Shrimp pigmentation with natural carotenoids. Feed Technology, Aquaculture Asia-Pacific Magazine, pp 34–35

Buttle LG, Crampton VO, Williams PD (2001) The effect of feed pigment type on flesh pigment deposition and colour in farmed Atlantic salmon, *Salmo salar* L. Aquac Res 32:103–111

Chakraborty S, Santra SC (2008) Biochemical composition of eight benthic algae collected from Sunderban. Indian J Mar Sci 37(3):329–332

Cruz-Suarez LE, Antimo-Perez JS, Luna-Mendoza N, Tapia-Salazar M, Ricque-Marie D, (2000) Relaciones proteına renergıa y proteına vegetalranimal optimas en alimentos de engorda para Litopenaeus Õannamei y L. stylirostris. In: Cruz-Suarez, L.E., Ricque-Marie, D., Tapia-Salazar, M., Olvera-Novoa, M.A., Civera-Cerecedo, R. Eds., Advances en Nutricion Acuıcola V—Memorias del Quinto Simposio Ž. Internacional de Nutricion Acuıcola, Merida, Yucatan, 19–20 Noviembre de 2000. Universidad Autonoma de Nuevo Leon, San Nicolas de los Garza, Mexico, compact disk in press

Cruz-Suárez LE, Tapia-Salazar M, Nieto-López MG, Guajardo-Barbosa C, Ricque-Marie D (2009) Comparison of *UlvA0020clathrata* and the kelps *Macrocystis pyrifera* and *Ascophyllum nodosum* as ingredients in shrimp feeds. Aquac Nutr 15:421–430

Daniels WH, Robinson EH (1986) Protein and energy requirements of juvenile red drum (*Sciaenops ocellatus*). Aquaculture 53:243–252

Darachai J, Piyatiratitivorakul S, Kittakoop P, Nitithamyong C, Menasveta P (1998) Effect of astaxanthin on larval growth and survival of giant tiger prawn, *Penaeus monodon*. In: Flegel TW (ed) Advances in shrimp biotechnology. National Center for Genetic Engineering and Biotechnology, Bangkok, pp 117–121

Gomes E, Dias J, Silva P, Valente L, Empis J, Gouveia L, Bowen J, Young A (2002) Utilization of natural and synthetic sources of carotenoids in the skin pigmentation of gilthead seabream (*Sparus aurata*). J Eur Food Res Technol 214:287–293

Harker M, Tsavalos AJ, Young AJ (1996) Factors responsible for astaxanthin formation in the chlorophyte *Haematococcus pluvialis*. Bioresour Technol 55:207–214

Hasan MR (2001) Nutrition and feeding for sustainable aquaculture development in the third millennium. In: Aquaculture in the third millennium. Technical proceedings of the conference on aquaculture in the third millennium, Bangkok, Thailand, 20–25 February 2000. NACA, Bangkok and FAO, Rome, pp 193–219

Hashim R, Mat-Saat NA (1992) The utilization of seaweed meals as binding agents in pellet feeds for snakehead (*Channa striatus*) fry and their effects on growth. Aquaculture 108:299–308

Ibrahim A, Shimizu C, Kono M (1984) Pigmentation of culture red sea bream, *Chrysophrys major*, using astaxanthin from Antarctic krill, *Euphausia superba*, and a mysid, *Neomysis* sp. Aquaculture 38:45–57

Jamu DM, Ayinla OA (2003) Potential for the development of aquaculture in Africa. Naga 26:9–13

Jeffrey SW, Humphrey GR (1975) New spectrophotometric equations for determining chlorophyll a, b, c1 and c2 in higher plants, algae and natural phytoplankton. Biochem Physiol Pflanz Bd 167:191–194

Johnson EA, Conklin DE, Lewis MJ (1977) The yeast *Phaffia rhodoyma* as a dietary pigment source for salmonids and crustaceans. J Fish Res Board Can 34:2417–2421

Kader MA, Hossain MA, Hasan MR (2005) A survey of the nutrient composition of some commercial fish feeds available in Bangladesh. Asian Fish Sci 18:59–69

Kaushik S (1990) Use of alternative protein resources for the intensive rearing of carnivorous fish. In: Flos R, Tort L, Torres P (eds) Mediterranean aquaculture. Hellis Horwood Ltd, Chichester, pp 125–138

Khan MA, Jafri AK, Chadha NK (2004) Growth and body composition of rohu (*L. rohita*) fed compound diet: winter feeding and rearing to marketable size. J Appl Ichthyol 20:265–270

Kobayashi M, Kakizono T, Nishio N, Nagai S (1992) Effects of light intensity, light quality and illumination cycle on astaxanthin formation in a green alga *Haematococcus pluvialis*. J Ferment Bioeng 74:61–63

Lovell RT (1989) Nutrition and feeding of fish. Van Nostrand Reinhold, New York

Lowry OH, Rosebrough NJ, Farr AL, Randell RJ (1951) Protein measurements with folin-phenol reagent. J Biol Chem 193:1433–1437

Maciena MJ, Murphey BR (1988) Variation in the weight to length relationship among Florida and Northern large mough bass and their interspecific F1 hybrid. Trans Am Fish Soc 117:232–237

Meyers SP, Latscha T (1997) Carotenoids. In: DAbramo LRD, Conclin DE, Akiyama DM (eds) Crustacean nutrition, Advances in world aquaculture, vol 6. The World Aquaculture Society, Baton Rouge, pp 164–193

Mitra A, Choudhury A (1995) Causes of water pollution in prawn culture farms. Jr of Ind Ocen Stud 2(3):230–235

Mitra A, Chakraborty R, Banerjee K, Banerjee A, Mehta N, Berg H (2006) Study on the water quality of the shrimp culture ponds in Indian Sundarbans. Indian Sci Cruiser 20(1):34–43

Mohanty SN, Das KN, Sarkar S (1995) Effect of feeding varying dietary formulations on body composition of rohu fry. J Aquac 3:23–28

Moretti VM, Mentasti T, Bellagamba F, Luzzana U, Caprino F, Turchini GM, Giani I, Valfre F (2006) Determination of astaxanthin stereoisomers and colour attributes in flesh of rainbow trout (*Oncorhynchus mykiss*) as a tool to distinguish the dietary pigmentation source. J Food Addit Contam 23:1056–1063

Moss SM (1994) Growth rates, nucleic acid concentrations, and RNA/DNA ratios of juvenile white shrimp, *Penaeus vannamei* Boone, fed different algal diets. J Exp Mar Biol Ecol 182:193–204

Mukhopadhyay N, Ray AK (1999) Improvement of quality of sesame (*Seasamum indicum*) seed meal protein with supplemental amino acids in feeds for rohu, *Labeo rohita*, (Hamilton), fingerlings. Aquac Res 30:549–557

Mukhopadhyay N, Ray AK (2001) Effect of amino acids supplementation on the nutritive quality of fermented linseed meal protein in the diets for rohu, *Labeo rohita* (Hamilton), fingerlings. J Appl Ichthyol 17:220–226

National Research Council (U.S) (1983) Sub-committee on Warm water Fish Nutrition, National Research Council

Nickell DC, Bromage NR (1998) The effect of timing duration of feeding astaxanthin on the development and variation of fillet color and efficiency of pigmentation in rainbow trout *(Oncorhyncus mykiss)*. Aquaculture 169:233–246

NRC (1983) Nutrients requirements of warm water fishes and shell-fishes. National Academy Press, Washington, DC, 102 pp

Okuzumi J, Takahashi T, Yamane T, Kitao Y, Inagake M, Ohya K, Nishino H, Tanaka Y (1993) Inhibitory effects of fucoxanthin, a natural carotenoid, on N-ethyl-N'-nitro-N-nitrosoguanidine-induced mouse duodenal carcinogenesis. Cancer Lett 68:159–168

PeñafloridaV, Golez NV (1996) Use of seaweed meals from *Kappaphycus alvarezii* and *Gracilaria heteroclada* as binders in diets for juvenile shrimp *Penaeus monodon*. Aquacul 143:393–401

Phillips AM (1972) Calorie and energy requirements. In: Halver JE (ed) Fish nutrition. Academic Press, New York, pp 2–29

Prather EE, Lovell RT (1973) Response of intensively fed channel catfish to diets containing various protein energy ratio. Proc 27th South-Eastern Assoc Game Fish Comm 27:455–459

Rajkhowa I (2005) Action in aquaculture – opportunities in a quaint specialization. Business Today (May 22 Issue):131

Saha SB, Ghosh BB, Gopalakrishnan V (1995) Plankton of Hooghly estuary with special reference to salinity and temperature. J Mar Biol Assoc India 17(1):107–120

Sarada R, Tripathi U, Ravishankar GA (2002) Influence on stress on astaxanthin production in *Haematococcus pluvialis* grown under different culture conditions. Proc Biochem 37:623–627

Satoh S (2000) Common carp, *Cyprinus carpio*. In: Wilson RP (ed) Handbook of nutrient requirement of finfish. CRC Press, Boca Raton/Ann Arbor/Boston/London, pp 55–68

Schuep W, Schierle J (1995) Astaxanthin determination of stabilized, added astaxanthin in fish feeds and pre-mixes. In: Carotenoids isolation and analysis, vol 1. Birkhauser Verlag, Basel, pp 273–276

Shyong WJ, Huang CH, Chen HC (1998) Effects of dietary protein concentration on growth and muscle composition of juvenile. Aquaculture 167:35–42

Simpson KL, Chichester CO (1981) Metabolism and nutritional significance of carotenoids. Annu Rev Nutr 1:351–374

Storebakken T, No HK (1992) Pigmentation in rainbow trout. Aquaculture 100:209–229

Strickland JDH, Parsons TR (1968) A manual for seawater analysis. Bull Fish Res Board Can 167:11–131

Strickland JDH, Parsons TR (1972) A practical handbook of seawater analysis. J Fish Res Board Can Ottawa 167:311

Suarez-Garcia HA (2006) Efecto de la inclusion de alginate y harina de algas Sargassum sp y *Macrocystis pyrifera sobre la estabilidad en agua,* digestibilidad del alimento y sobre el crecimiento del camaron blanco *Litopenaeus vannamei.* Undergraduate thesis, Universidad Autonoma de Nuevo Leon, Mexico

Tecator (1983) Fat extraction on feeds with the Soxtec System HT – the influence of sample preparation and extraction media. Application note AN 67/83 (1983.06.13). Soxtec System HT Manual, Tecator AB, Sweden

Tjahjono AE, Hayama Y, Kakizono T, Terada Y, Nishio N, Nagai S (1994) Hyper-accumulation of astaxanthin in a green alga *Haematococcus pluvialis* at elevated temperatures. Biotechnol Lett 16:133–138

Torrisen OJ, Hardy RW, Shearer KD (1989) Pigmentation of salmonids – carotenoid deposition and metabolism. CRC Crit Rev Aqua Sci 1:209–225

Trevelyan WE, Harrison JS (1952) Studies on yeast metabolism. 1. Fractionation and microdetermination of cell carbohydrates. Biochem J 50:298–303

United Nations Educational (1987) Scientific and Cultural Organization Convention concerning the Protection of the World Cultural and Natural Heritage Report of the World Heritage Committee Eleventh session (UNESCO headquarters, 7–11 December 1987)

Valente LMP, Gouveia A, Rema P, Matos J, Gomes EF, Pinto IS (2006) Evaluation of three seaweeds *Gracilaria bursapatoris*, *Ulva rigida* and *Gracilaria cornea* as dietary ingredients in European seabass (*Dicentrarchus labrax*) juveniles. Aquaculture 252:85–91

Van der Meer MB, Zamora JE, Ver degem MCJ (1997) Effect of dietary lipid level on protein utilization and the size and proximate composition of body compartments of *Colossoma macropomum* (Cuvier). Aquac Res 28:405–417

Walkey A, Black IA (1934) An examination of the effect of the digestive method for determining soil organic matter and a proposed modification of the chronic and titration method. Soil Sci 37:29–38

White DA, Page GI, Swaile J, Moody AJ, Davies SJ (2002) Effect of esterification on the absorption of astaxanthin in rainbow trout, *Oncorhynchus mykiss* (Walbaum). Aquac Res 33:343–350

Wilson RP (2000) Channel catfish, *Ictalurus punctatus*. In: Wilson RP (ed) Handbook of nutrient requirement of finfish. CRC Press, Boca Raton/Ann Arbor/Boston/London, pp 35–53

WWF-India (2006) Training manual on ecofriendly and sustainable fishery, New Delhi, 130 pp

Yan X, Chuda Y, Suzuki M, Nagata T (1999) Fucoxanthin as the major antioxidant in *Hijikia fusiformis*, a common edible seaweed. Biosci Biotechnol Biochem 63:605–607