A PRELIMINARY ACCOUNT OF THE BIOLOGY AND FISHERY OF THE RAZOR-SHELL, *SOLEN KEMPI* PRESTON, FROM RATNAGIRI IN MAHARASHTRA STATE

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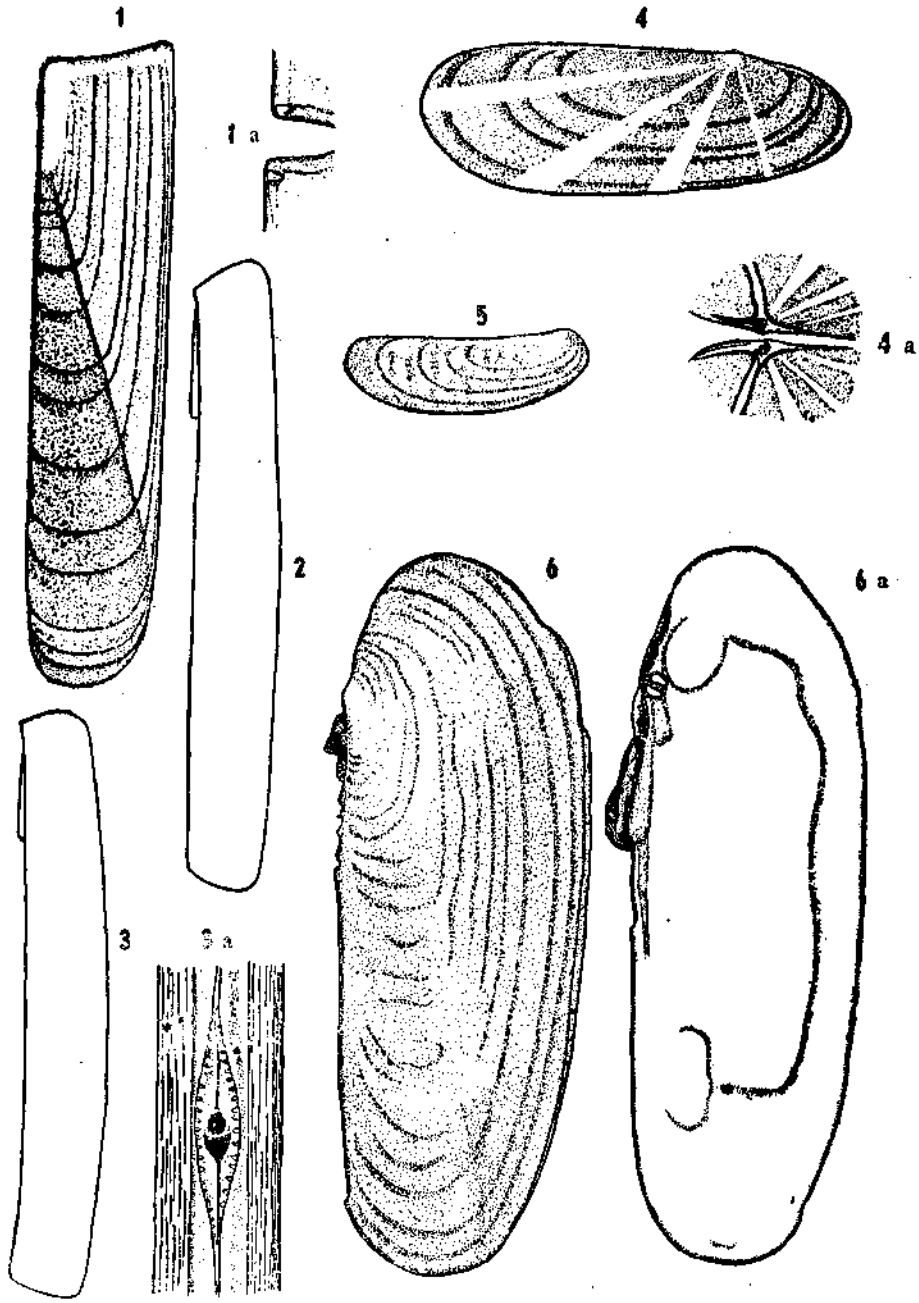
Introduction

The present paper is based on periodical samples of the razor-shell, *Solen kempi*, obtained for a period of about 21 months in 1960–61 from Gav-khadi near Ratnagiri where it forms fairly productive beds which are regularly fished by the local people chiefly for culinary purpose. Besides Gav-khadi, only in a few other places like Ganpatiphoola and Devgod in Ratnagiri District there exist minor beds of *Solen*. But by transplantation of the clams from these beds to areas where similar environmental conditions exist it is possible to increase the resources several times to meet the prevailing demand. In the following account an attempt is made to furnish particulars of the existing conditions of the fishery along with information on taxonomy and some aspects of biology of the species.

Taxonomy and Distribution of the Species of *Solen* on the Indian Coasts

The family Solenidae Leach includes elongated bivalves living under a marine or estuarine habitat and characterised by the presence of long equivalve shells with periostracum, an external ligament, flat umbones and valves gaping at each end; a powerful cylindrical foot without byssus adapted for burrowing; narrow gills and usually short siphons. Razor-shells, sunset shell, etc., are included.

Under Solenidae there are two clearly distinguishable subfamilies, *viz.* Novaculininae and Soleninae. The former is characterised by the body being widened laterally and gills non-plicate. It is represented by *Novaculina gangetica* Benson. The latter has a laterally flattened body with narrow



FIGS. 1–6 *a*. Fig. 1. *Solen lamarckii*, lateral view, natural size. Fig. 1 *a*. Anterior region of the valves, inner view. Fig. 2. *Ensis siliqua*, outline of the shell, ×3/5. Fig. 3. *Ensis arcuata*, outline of the shell, ×3/5. Fig. 3 *a*. *Ensis*, mantle showing fourth aperture, ×2⅔ (Figs. 2 to 3 *a* after Holme, 1951). Fig. 4. *Siliqua radiata*, lateral view, natural size. Fig. 4 *a*. Anterior region of the valves, inner view. Fig. 5. *Phaxas cultellus*, lateral view, natural size. Fig. 6. *Cultellus maximus*, lateral view, ×½. Fig. 6 *a*. Inner view (Figs. 6 and 6 *a* after Chenu, 1843).

ventral surface and plicate gills. It includes *Solen* and a few other genera. A third subfamily Solecurtinae has also been recognised by Ghosh (1920) and is represented among others by *Solecurtus philippinarum* Deshayes and *Solecurtus* (*Azor*) *coarctatus* (Gmelin). Thiele (1935) and Gravely (1941) have included the members of this subfamily under the family Psammobidae.

The subfamily Soleninae includes the genera *Solen, Siliqua, Phaxas, Cultellus, Ensis, Pharus* and *Pharella* of which the first four are known to occur from the Indian coasts.

The members of the genus *Solen* possess an elongated shell with only one tooth in each valve; a long and narrow body; anterior and posterior margins of mantle being straight and sloping; pedal aperture confined to the anterior regions; siphons distally fringed with tentacles; anterior adductor muscle long and posterior adductor muscle usually oval; foot cylindrical, slightly flattened from side to side with anterior extremity dilated; labial palps long and tapering behind; gills narrow and long extending into the proximal regions of the branchial siphon; pyloric region of the stomach with a caecum arising ventrally and passing forwards; intestine with an anterior limb coiled closely and a posterior limb in one or more folds. In *Siliqua* (Figs. 4, 4 *a*) the front and hind margins of the shell which is extremely thin, are rounded, with the hinge having two teeth on the right valve and three on the left; the inner surface of the shell bears a ridge extending from the umbo towards the ventral margin. In *Phaxas* (Fig. 5), as in *Siliqua*, the anterior and posterior margins of the shell are rounded but without a ridge on the inner surface of the valves; lower margin lightly arched; texture delicate; the anterior muscle scar is elongate and the shell in front of it is somewhat thickened. *Cultellus* (Figs. 6, 6 *a*) is closely related to *Phaxas*, but in the former the shell is large and thick and the anterior muscle scar is round with its upper margin thickened.

In *Solen* the mantle lobes are fused with each other, but the fusion is incomplete leaving gaps, known as apertures of which there are three, the anterior one (pedal aperture) for the protrusion of the foot and two posterior ones (anal and branchial apertures) for the anal and branchial siphons; the siphons are fused to a single piece. In *Ensis* (Figs. 2, 3, 3 *a*) a fourth aperture in the ventral margin of the fused mantle lobes is also present and the siphons are fused together. In *Pharus* the fourth aperture is continuous with the pedal aperture and the siphons are long and separate, whereas in *Pharella* there is no fourth aperture and the siphons are short and separate.

The salient features of the species of *Solen* commonly occurring in the Indian waters are described below:—

1. *Solen lamarckii* Deshayes

(Figs. 1, 1 *a*)

Solen lamarckii Chenu, *Illustr. Conchyl.*, 1843-45, pl. 1, figs. 2, 3 & 4.

Solen lamarckii Sowerby, in Reeve, *Conch. Icon.*, **19**, 1874, *Solen*, pl. iv, fig. 16.

Solen lamarckii Clessin, in Martini-Chemnitz, *Conch. Cab.*, **11**, Bd. 3 Abth., 1888, p. 25, pl. viii, fig. 3.

Solen lamarckii Dautzenberg and Fisher, *Jour. de Conchyl.*, **54**, 1906, p. 220.

Solen lamarckii Gravely, *Bull. Mad. Govt. Mus.* (*Nat. Hist.*), **5**, No. 1, 1941, p. 63, fig. 23 *b*.

Solen lamarckii Satyamurti, *Bull. Mad. Govt. Mus.*, N.S. (*Nat. Hist.*), **1**, No. (2), pt. 7, 1956, p. 159, pl. xxiv, fig. 2.

A fairly large form; shell four to five times nearly as long as high; surface with indistinct purplish colour bands; front margin truncated and slightly sloping; hinge tooth close behind the front margin of each valve. Habitat—marine; occurs all along the Indian coasts.

2. *Solen truncatus* Wood

Solen truncatus Wood, Reeve, *Conch. Icon.*, **19**, 1874, *Solen*, pl. i, fig. 1.

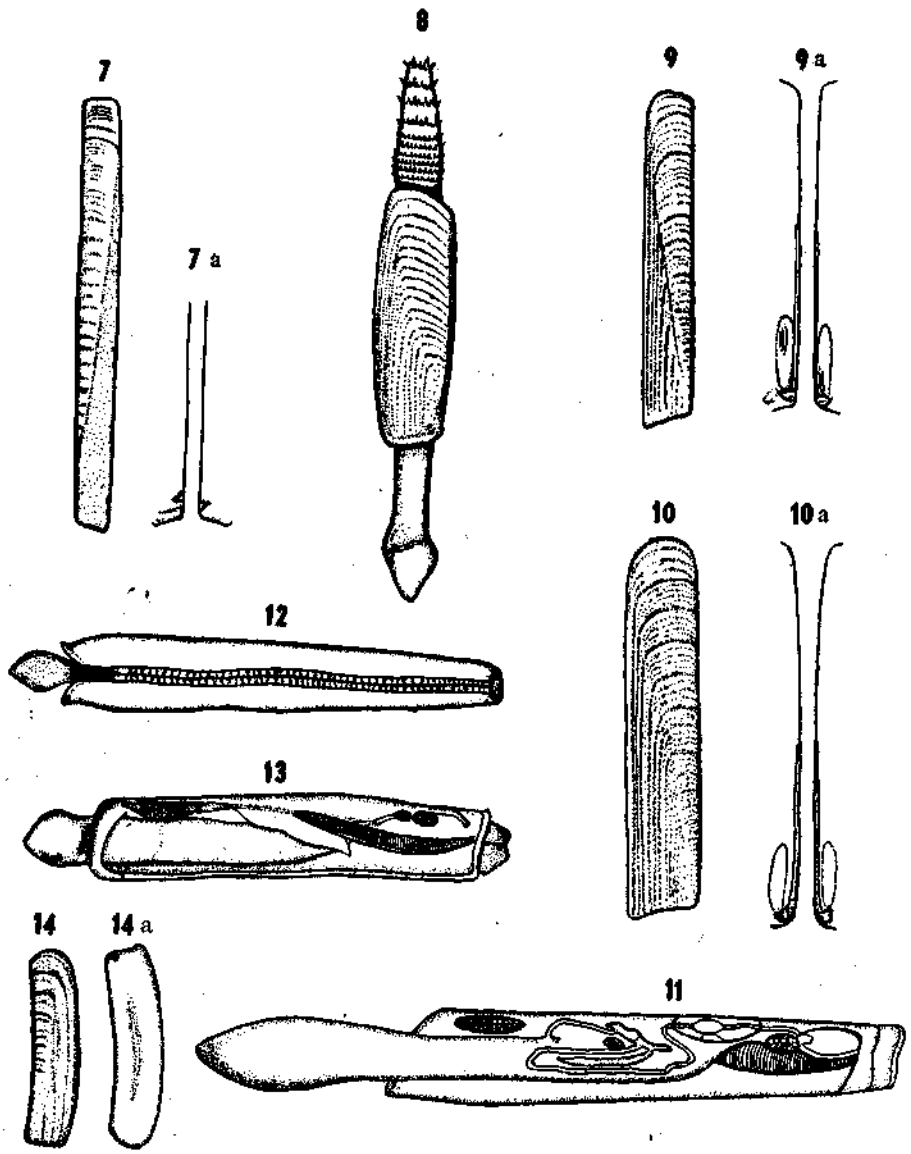
Solen truncatus Gravely, *Bull. Mad. Govt. Mus.* (*Nat. Hist.*), No. 1, 1941, p. 63.

A form of medium size; shell with upper and lower margins straight and parallel; posterior margin abruptly truncate and sloping slightly backwards from top to bottom; colour bands strongly developed. Habitat—marine; widely distributed.

3. *Solen linearis* Spengler

(Figs. 7, 7*a*)

Solen linearis Spengler, in Reeve, *Conch. Icon.*, **19**, 1874, *Solen*, pl. 4, fig. 22.



FIGS. 7–14 *a*. Fig. 7. *Solen linearis*, lateral view, natural size. Fig. 7 *a*. Anterior region of the valves, inner view. Fig. 8. *Solen aquae-dulcioris*, living specimen, lateral view, natural size (after Annandale and Kemp, 1916); Fig. 9. *Solen kempi*, lateral view, about 1½ natural size. Fig. 9 *a*. Inner view. Fig. 10. *Solen annandalei*, lateral view, about 1½ natural size. Fig. 10 *a*. Inner view (Figs. 9–10 *a* after Preston, 1915). Fig. 11. *Solen kempi*, soft parts, ×about 3; Fig. 12. *Solen gravelyi*, soft body, ventral view, ×about 3. Fig. 13. *Solen gravelyi*, soft parts, lateral view, ×about 3 (Figs. 11–13 after Ghosh, 1920). Fig. 14. *Solen aspersus*, lateral view, natural size. Fig. 14 *a*. Inner view.

Solen linearis Spengler, Gravely, *Bull. Mad. Govt. Mus.* (*Nat. Hist.*), **5,** No. 1, 1941, p. 63.

Shell very much elongated, being ten to twelve times as long as high; hinge tooth well behind the front margin. Habitat—marine; washed out shells were collected from Palk Bay near Devipatnam; also recorded from the Madras beach.

4. *Solen aspersus* Dunker

(Figs. 14, 14 *a*)

Solen aspersus Dunker, *Proc. Zool. Soc. London,* 1861, p. 420.

Solen aspersus Sowerby, in Reeve, *Conch. Icon.*, **19,** 1874, *Solen,* pl. vii, fig. 33.

Solen aspersus Dunker, Satyamurti, *Bull. Mad. Govt. Mus.*, N.S. (*Nat. Hist.*), **1,** No. 2, pt. 7, 1956, p. 159.

A small form; shell slightly curved in its long axis with the upper surface concave and the ventral margin a little convex; surface pale brown and mottled with purplish markings; front and hind margins truncated; hinge tooth close behind the front margin in the left valve and almost at the margin on the right one. Habitat—marine; recorded from Pamban.

5. *Solen aquae-dulcioris* (Ghosh)

(Fig. 8)

Solen fonesi Dunker, *Proc. Zool. Soc., London,* 1861, p. 419.

Solen truncatus Wood, Preston, *Rec. Indian Mus.,* 1916, **12,** p. 37.

Solen ? *fonesi* Dunker, Annandale and Kemp, *Mem. Indian Mus.*, **5,** 1916, p. 354, fig. v, pl. xvi, fig. 7.

Solen ? *fonesi* Dunker, Ghosh, *Mem. Indian Mus.*, **5,** 1916, figs. 1–3, pp. 367–74.

Neosolen aquae-dulcioris Ghosh, *Rec. Indian Mus.*, **19,** 1920, pp. 57–58, pl. ii, fig. 12, pl. iii, figs, 13 & 14.

Neosolen aquae-dulcioris Ghosh, Thiele, *Handbuch. Syst. Weicht.*, 1935, Bd. ii, p. 923.

Solen aquae-dulcioris (Ghosh), Gravely, *Bull. Mad. Govt. Mus.*, (*Nat. Hist.*) **5,** 1941, No. 1, pp. 63–64.

A very small form; shell not more than four times as long as high; periostracum horn coloured; anterior and posterior extremities prominently

rounded; anterior mantle margin slightly curved; siphon long, segmented, each segment with a tentacular fringe at its distal end; anterior adductor muscle elongated and narrow; posterior adductor muscle oval and smaller in size than the retractor pedis posterior; foot elongated, cylindrical, slightly flattened at the sides, stout towards apex and forms a distinct rounded swelling with a conical process at its tip; gills short; body considerably abbreviated antero-posteriorly in comparison with other species of *Solen*. Habitat—brackish water; recorded from Chilka Lake (Orissa) and Ennur backwaters (near Madras).

6. *Solen kempi* Preston

(Figs. 9, 9 *a*, 11)

Solen kempi Preston, *Rec. Indian Mus.*, **11**, 1915, p. 305, figs. 18, 18 *a*.

Solen kempi Preston, Annandale and Kemp, *Mem. Indian Mus.*, **5**, 1916, p. 355.

Solen annandalei Preston, Annandale and Kemp, *Ibid.*, **5**, 1916, pl. xvi, fig. 8.*

Solen kempi Preston, Ghosh, *Rec. Indian Mus.*, **19**, 1920, pp. 52, 53.

Solen kempi Preston, Gravely, *Bull. Mad. Govt. Mus.*, **5**, No. 1, 1941, pp. 63–64.

Shell small, about six times as long as high, comparatively narrower than *S. annandalei*; periostracum yellowish-brown, glossy, shining; anterior region obliquely truncate; posterior region rounded; cardinal tooth in the right valve with a shallow groove throughout its breadth; tooth in the left valve is more rigidly erect than in *S. annandalei*; dorsal margin of soft body slightly concave in the anterior region and convex in the posterior; siphon long, segmented, distal end of branchial siphon with six small prominences, pedal aperture bounded by pedal valves, with a small tentacle-like process in the dorsal aspect where they meet; foot long, flattened and about half the body length; anterior adductor muscle about five times as long as deep; posterior adductor muscle slightly elongated; gills elongate, but their visceral portion is small; body elongated more in the anterior region than in the posterior. Habitat—brackish waters; Chilka Lake (Orissa), Ennur (near Madras) and Gav-khadi (near Ratnagiri).

* Figures of *S. kempi* and *S. annandalei* inadvertently transposed as stated by Ghosh (1920).

7. *Solen annandalei* Preston

(Figs. 10, 10 *a*)

Solen annandalei Preston, *Rec. Indian Mus.*, **11**, 1915, pp. 304–05, figs. 17, 17*a*.

Solen annandalei Preston, Annandale and Kemp, *Mem. Indian Mus.* **5**, 1916, p. 355.

Solen kempi Preston, Annandale and Kemp, *Ibid.*, **5**, 1916, pl. xvi, fig. 9*.

Solen annandalei Preston, Gravely, *Bull. Mad. Govt. Mus.* (*Nat. Hist.*), **5**, No. 1, 1941, pp. 63–64.

Shell small, about six times as long as high, yellowish-brown, with glossy periostracum; dorsal and ventral margins straight; anterior side obliquely forwards from above downwards; posterior region obtuse and rounded at the ventral and the dorsal corners; right valve with a single cardinal tooth which is grooved below. Habitat—brackish waters; Chilka Lake and Ennur backwaters.

8. *Solen gravelyi* Ghosh

(Figs. 12, 13)

Solen sp. Gravely, *Rec. Indian Mus.*, **16**, 1919, p. 396.

Solen gravelyi Ghosh, *Ibid.*, **19**, 1920, pp. 54–56, pl. ii, figs. 6–9.

Shell small, thin, translucent with whitish epidermis; length four to five times its breadth; anterior margin nearly straight and directed from above a little forward; antero-superior and antero-inferior corners rounded; with a strongly marked constriction close behind and parallel to anterior margin; posterior margin slightly convex; umbonal teeth anterior; mantle lobes bounding, pedal aperture thick and muscular, presenting a groove on their outer surface to receive the constriction on the valve at the same position; anterior adductor muscle long and narrow; posterior adductor muscle small and oval; foot short, cylindrical, slightly flattened laterally, with a knob-like swelling ending in a blunt point at free end; inner lamellae of the inner gill are free in the visceral portion and also in the region of the cloaca. Habitat—brackish waters; Chandipore, Balasore (Orissa).

Environmental Conditions and the Extent of the Beds of *Solen kempi* in the Vicinity of Ratnagiri

The material of *Solen kempi* for the present study was obtained from the beds situated on the southern bank of Purungarh creek (long. E. 73° 19′31″;

* *See* foot-note on p. 548.

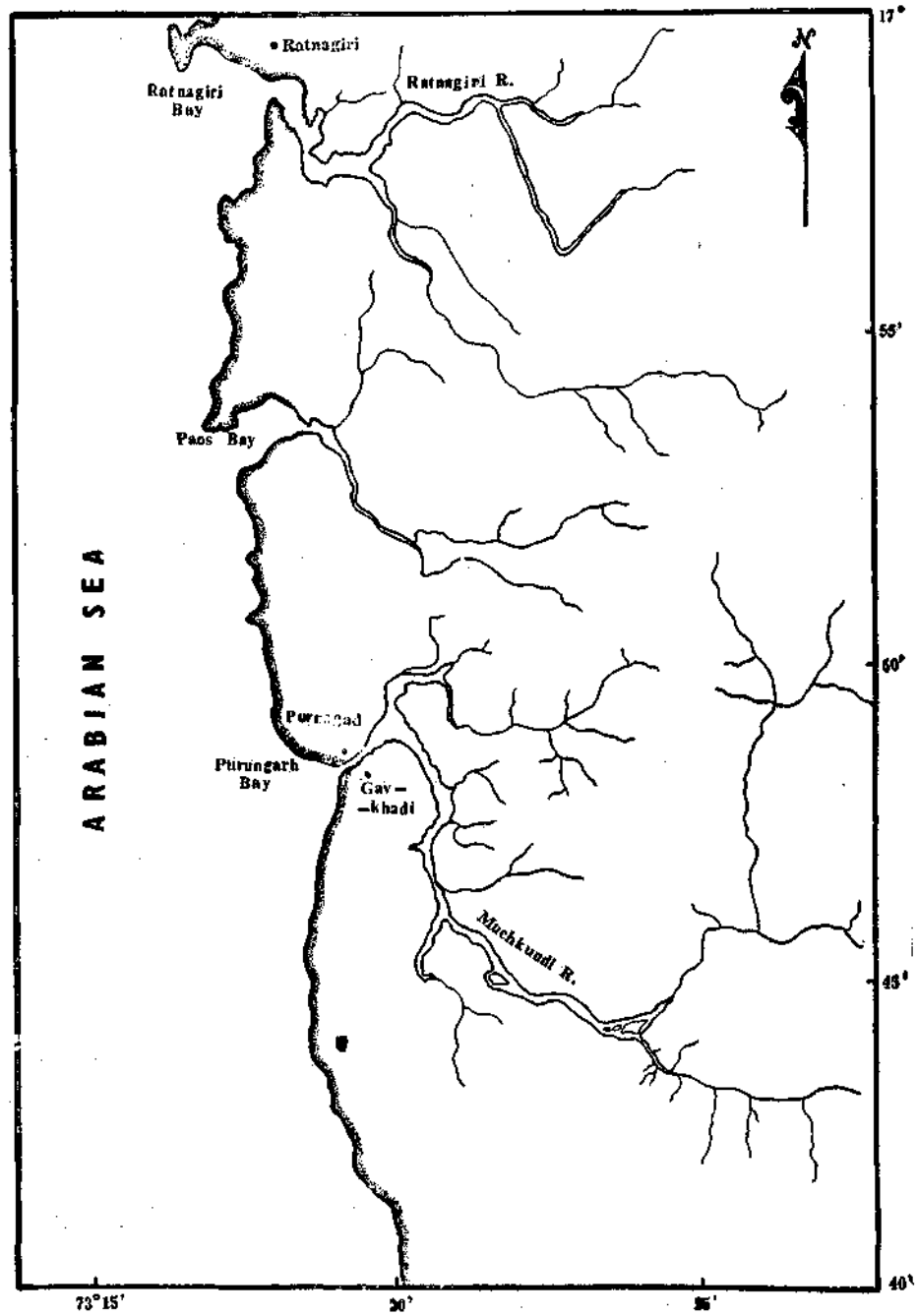


FIG. 15. The vicinity of Purungarh Bay, Gav-khadi village and Ratnagiri (adapted from the Admiralty Chart).

lat. N. 16° 48′ 47″) near Gav-khadi village in Ratnagiri District of Maharashtra State. The river Muchkundi flows into the Purungarh creek which communicates with the Arabian Sea at Purungarh Bay (Fig. 15). Purnagad village is on the northern bank of the Purungarh creek; the approach to the former is by a motorable road 13 miles from Ratnagiri and by crossing the creek by ferry one reaches the clam beds in the vicinity of Gav-khadi (Fig. 16).

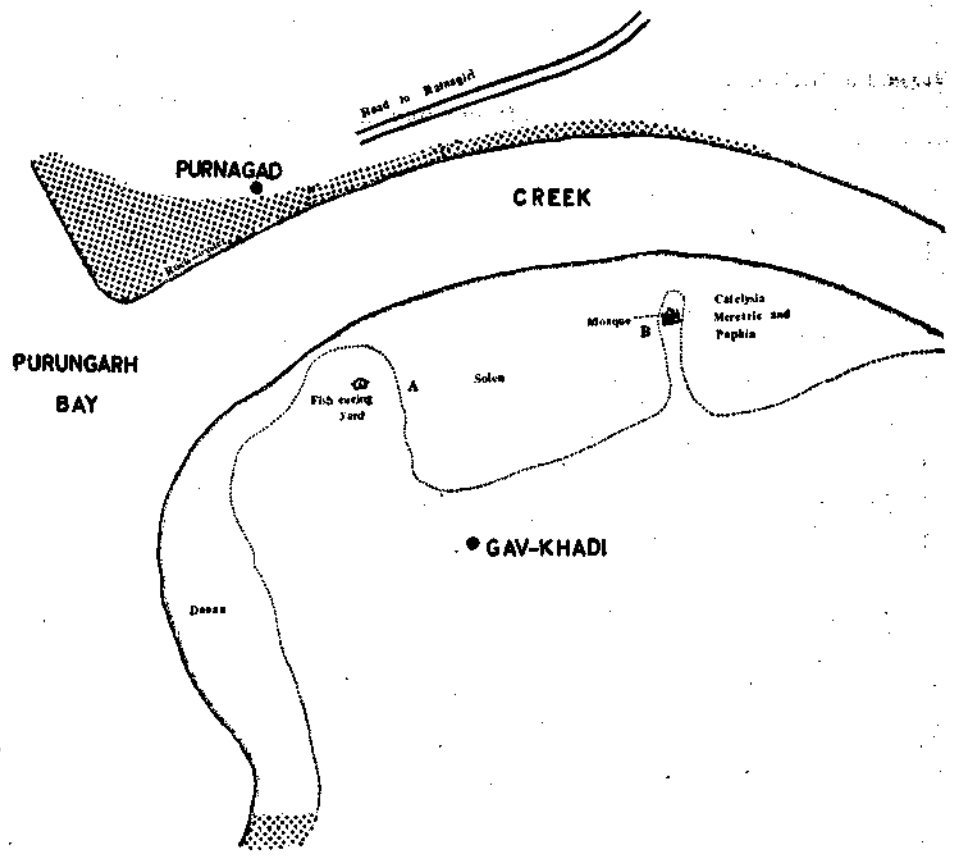


FIG. 16. Showing the location of *Solen* and other clam beds near Gav-khadi (not drawn to scale).

Where the clam beds exist there is a good amount of silt deposited by the river enabling the shellfish and other intertidal organisms to thrive well. The area adjoining the bay and bordering the westernmost region of the creek is sandy, elevated three to five feet above the sea-level and not submerged even at high tides. This area screens off the beds lying to its east from the pounding action of the surf. Next to it are the *Solen* beds about

two acres in extent. This area is little inclined towards the creek allowing the drainage of rain-water from the adjacent fields. In continuation of the beds of *Solen* there are in the eastern region small beds of other clams, *viz.*, *Meretrix meretrix*, *Paphia* sp. and *Catelysia opima*. *Solen* is not altogether unrepresented in this area as a few individuals can be collected at any time during the year (Fig. 16).

The *Solen* beds are in shallow waters from high watermark to a little beyond the low watermark. The entire area of the beds is completely submerged at high tides but a greater portion of it is exposed at the receding tides. At the bottom is an admixture of silt and fine sand. In beds near high watermark only clams of larger size over 40 mm. in length are usually found distributed very sparsely and near the low watermark medium-sized to larger ones, measuring over 25 mm. in length in fair numbers. In the adjacent area in slightly deeper waters clams of all sizes occur, including small ones from 4 to 20 mm., in large numbers from November to April. Small-sized ones in the low watermark zone also occur in the same months but in very few numbers. The relative abundance of the clams of different sizes in the three areas indicates that the setting of the seed clams takes place at first in a little deeper water and the young, as they grow older, move more towards the shallower region of the beds covered by high tides.

The shore on the northern bank of the creek is rocky where the oyster, *Crassostrea cucullata*, thrives. Several species of *Donax* occur on the surf-beaten sandy shore of the bay to the south of the creek.

The waters in the regions where the *Solen* beds are situated are subject to wide fluctuations in certain physico-chemical factors during the course of the year in different periods, *viz.*, summer from March to May, south-west monsoon from June to September, post-monsoon in October-November and winter from December to February. In summer the river completely dries up, the water level over the beds falls and semi-drought conditions prevail. In the monsoon months the region is flooded both with the river-water and the rain-water draining from the land. In the post-monsoon months the tidal flow is strong up to about five miles in the upper reaches of the river.

The seasonal variations in salinity and temperature of the waters over the beds are shown in Table I and Fig. 17 for the period of observations from April 1960 to December 1961.

In general, in the late summer months of April and May both salinity and temperature are very high; in June and July which are monsoon months

TABLE I

Showing the monthly averages of temperature and salinity of the waters over the Solen *beds from April* 1960 *to December* 1961

Month	Temperature °C.	Salinity ‰	Month	Temperature °C.	Salinity ‰
1960			1961		
April ..	28·0	36·8	January ..	26·5	30·5
May ..	29·5	35·6	February ..	27·2	34·9
June ..	26·2	5·4	March ..	28·8	34·7
July ..	26·4	5·4	April ..	28·7	36·3
August ..	27·8	4·8	May ..	29·8	34·8
September ..	27·8	13·3	June ..	27·1	15·4
October ..	29·3	18·5	July ..	27·3	1·2
November ..	28·8	29·0	August ..	27·5	3·5
December ..	28·4	30·9	September ..	28·0	14·0
			October ..	28·4	19·2
			November ..	28·5	26·4
			December ..	28·0	31·6

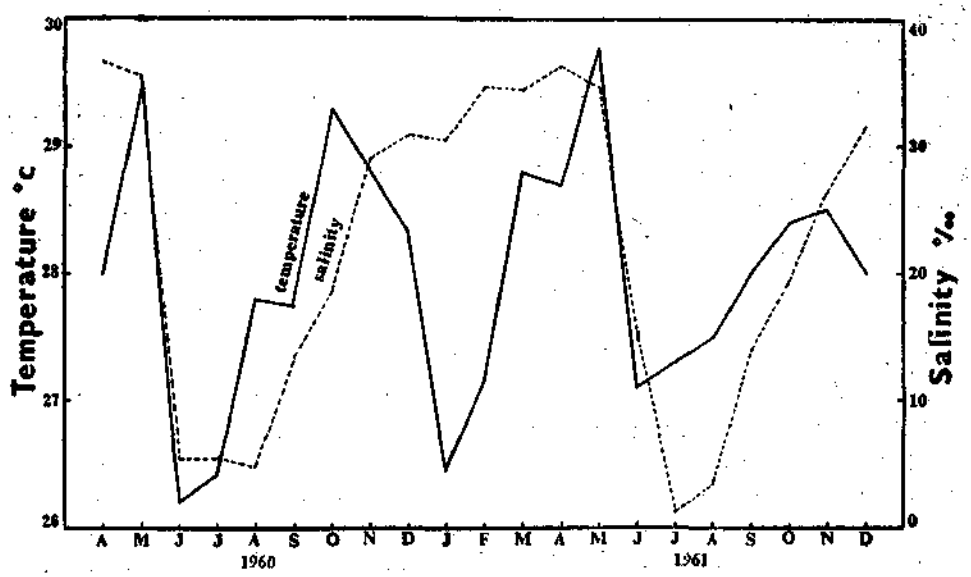


FIG. 17. Seasonal variations of salinity and temperature of waters over the *Solen* beds.

they are very low; in the later part of monsoon and earlier part of post-monsoon months, *viz.*, August, September, October and even November they begin to show a gradual increase. In the later part of post-monsoon and earlier part of winter, *viz.*, November, December and January, the temperature falls rapidly while the salinity remains fairly high, but commencing from about January through the later part of winter and earlier part of summer there is a rapid increase of temperature and the prevailing high salinity shows a still further rise.

Growth of *Solen kempi*

Age and growth have been studied from random samples which were collected from an area one meter wide starting from the high watermark up to low watermark. Later it was found that the setting of the seed clams took place in a little deeper water along the border of the creek beyond the low watermark. Hence from November 1960 onwards this area was also included for the purpose of collecting samples. The larger clams, after dislodging them from the burrows, were hand-picked while the smaller ones were obtained by sieving the bottom soil with a sieve, the mesh size of which was 2 mm.

From the gonadial examination and the observations on the occurrence of the seed clams it has been concluded that spawning starts by about October-November and lasts till about March-April. The peak of spawning intensity appears to be at about the commencement of the breeding season. The size frequency distribution of the clams obtained in the samples from April 1960 to December 1961 is shown in Table II and Figs. 18 and 19.

In the month of April 1960 the modal size of the sample is at 37·5 mm. (*a*), the minimum, 19·5 mm. and the maximum, 51 mm. It may be presumed that the modal size of 37·5 mm. is the result of active spawning by parental stock in October 1959 which indicates an average growth of about 6 mm. per month. In May 1960 the modal size has increased to 42·5 mm. (*a*). The minimum sized clams of 17·5 mm. from April and May samples are the result of late setting during the same spawning period, they having migrated subsequently from deeper waters to the low water region.

In the samples from June to September 1960 this mode remains stationary and this indicates a period when the growth of the clams is either nil or too negligible to be detected in groupings of 5 mm. intervals. In October 1960 the modal size has increased to 47·5 mm. (*a*) which may be considered as the average growth of the one-year old clams on the assumption that the peak spawning which has resulted in this group of clams had taken

TABLE II

Showing the size-frequency distribution of Solen kempi

Size groups (length in mm.)	17-4-1960 No. (%)	24-5-1960 No. (%)	20-6-1960 No. (%)	23-7-1960 No. (%)	19-8-1960 No. (%)	16-9-1960 No. (%)	23-9-1960 No. (%)	8-10-1960 No. (%)	23-10-1960 No. (%)	8-11-1960 No. (%)
2·5	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
7·5	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
12·5	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
17·5	4 (1·65)	1 (0·21)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
22·5	6 (2·48)	5 (1·06)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
27·5	6 (2·48)	21 (4·45)	2 (0·41)	4 (0·95)	5 (1·10)	4 (1·08)	.. ..	.. ..	.. ..	.. ..
32·5	50 (20·66)	59 (12·50)	12 (2·48)	29 (6·92)	47 (10·38)	16 (4·33)	2 (1·90)	.. ..	8 (3·49)	2 (1·36)
37·5	93 (38·43)	117 (24·79)	96 (19·88)	144 (34·38)	167 (36·87)	81 (21·96)	32 (30·48)	13 (7·70)	51 (22·27)	10 (6·80)
42·5	70 (28·93)	174 (36·86)	223 (46·17)	161 (38·42)	168 (37·09)	154 (41·74)	39 (37·15)	58 (34·32)	59 (25·76)	57 (38·78)
47·5	12 (4·96)	74 (15·68)	136 (28·57)	73 (17·42)	62 (13·68)	97 (26·29)	26 (24·76)	64 (37·86)	71 (31·00)	53 (36·05)
52·5	1 (0·41)	21 (4·45)	11 (2·28)	8 (1·91)	3 (0·66)	16 (4·33)	6 (5·71)	34 (20·12)	34 (14·86)	22 (14·97)
57·5	.. ..	.. ..	1 (0·21)	.. ..	.. ..	1 (0·27)	.. ..	.. ..	6 (2·62)	3 (2·04)
62·5	.. ..	.. ..	.. ..	.. ..	1 (0·22)	.. ..	.. ..	.. ..	.. ..	.. ..
Total ..	242 ..	472 .	483 ..	419 ..	453 ..	369 ..	105 ..	169 ..	229 ..	147 ..
Maximum	51·0	55·0	55·5	54·0	63·0	56·0	52·5	53·5	57·0	57·0
Minimum	19·5	20·0	29·0	29·0	27·0	28·0	33·5	36·0	33·0	33·0
Mean ..	37·52	40·31	42·88	41·01	40·25	42·59	42·60	46·02	44·47	45·63
S.D. ..	5·75	6·16	4·26	4·67	4·69	4·88	4·65	4·39	5·32	4·69
S.E. ..	0·37	0·28	0·19	0·23	0·22	0·25	0·46	0·34	0·38	0·39

TABLE II—(*Contd.*)

Size groups (length in mm.)	15-12-1960 No. (%)	27-12-1960 No. (%)	5-1-1961 No. (%)	16-1-1961 No. (%)	3-2-1961 No. (%)	12-2-1961 No. (%)	20-2-1961 No. (%)	4-3-1961 No. (%)	17-3-1961 No. (%)	2-4-1961 No. (%)
2·5	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	4 (3·67)
7·5	2 (1·03)	2 (1·33)	.. ..	11 (6·01)	.. ..	1 (0·73)	.. ..	.. ..	.. ..	4 (3·67)
12·5	11 (5·67)	9 (6·00)	3 (2·26)	10 (5·46)	2 (1·80)	7 (5·15)	3 (3·41)	1 (0·91)	3 (3·16)	.. ..
17·5	42 (21·65)	18 (12·00)	13 (9·76)	17 (9·29)	2 (1·80)	4 (2·94)	.. ..	.. ..	.. ..	.. ..
22·5	11 (5·67)	24 (16·00)	50 (37·60)	23 (12·57)	4 (3·61)	6 (4·41)	3 (3·41)	.. ..	.. ..	.. ..
27·5	1 (0·52)	22 (14·67)	47 (35·34)	64 (34·97)	14 (12·61)	17 (12·50)	12 (13·63)	4 (3·63)	1 (1·05)	1 (0·92)
32·5	.. ..	11 (7·33)	8 (6·02)	32 (17·49)	34 (30·63)	36 (26·47)	36 (40·91)	41 (37·27)	19 (20·00)	13 (11·93)
37·5	1 (0·52)	.. ..	.. ..	6 (3·28)	31 (27·93)	38 (27·94)	17 (19·32)	39 (35·46)	40 (42·11)	37 (33·94)
42·5	3 (1·54)	2 (1·33)	1 (0·75)	1 (0·55)	7 (6·31)	16 (11·77)	7 (7·95)	13 (11·83)	20 (21·05)	33 (30·27)
47·5	59 (30·40)	17 (11·34)	2 (1·50)	.. ..	5 (4·50)	3 (2·21)	3 (3·41)	4 (3·63)	5 (5·26)	7 (6·42)
52·5	49 (25·26)	29 (19·34)	6 (4·51)	8 (4·37)	5 (4·50)	4 (2·94)	6 (6·82)	5 (4·54)	6 (6·32)	4 (3·67)
57·5	14 (7·22)	15 (10·00)	3 (2·26)	7 (3·82)	7 (6·31)	4 (2·94)	1 (1·14)	3 (2·73)	1 (1·05)	5 (4·59)
62·5	.. ..	1 (0·66)	.. ..	4 (2·19)	.. ..	.. ..	.. ..	.. ..	.. ..	1 (0·92)
67·5	1 (0·52)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Total ..	194 ..	150 ..	133 ..	183 ..	111 ..	136 ..	88 ..	110 ..	95 ..	109
Maximum	66·0	65·0	60·00	63·0	60·00	60·0	58·0	58·5	56·5	61·0
Minimum	9·5	7·0	13·5	6·5	12·0	10·0	12·0	15·0	10·0	4·5
Mean	39·05	35·23	26·82	28·21	36·06	34·01	34·72	37·23	38·34	38·28
S.D.	16·26	15·68	9·06	12·10	9·33	9·57	8·44	6·83	7·39	11·36
S.E.	1·17	1·28	0·79	0·89	0·89	0·82	0·90	0·65	0·76	1·09

TABLE II—(*Contd.*)

Size groups (length in mm.)	24-4-1961 No. (%)	19-5-1961 No. (%)	16-6-1961 No. (%)	23-7-1961 No (%)	31-8-1961 No. (%)	24-9-1961 No. (%)	25-10-1961 No. (%)	9-11-1961 No. (%)	20-11-1961 No. (%)	11-12-1961 No. (%)
2·5	1 (0·93)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	9 (12·86)	4 (3·03)	9 (12·50)
7·5	10 (9·35)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	11 (15·71)	29 (21·97)	34 (47·22)
12·5	3 (2·81)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	12 (9·09)	22 (30·56)
17·5	1 (0·93)	.. ..	4 (3·20)	.. ..	.. ..	.. ..	.. ..	.. ..	1 (0·76)	6 (8·33)
22·5	1 (0·93)	2 (1·83)	6 (4·80)	14 (8·98)	4 (3·60)	.. ..	4 (4·35)	.. ..	.. ..	1 (1·39)
27·5	.. ..	8 (7·34)	1 (0·80)	16 (10·26)	11 (9·91)	5 (3·27)	7 (7·61)	1 (1·43)	.. ..	.. ..
32·5	.. ..	.. ..	5 (4·00)	2 (1·28)	14 (12·61)	5 (3·27)	6 (6·52)	2 (2·86)	.. ..	.. ..
37·5	22 (20·56)	3 (2·75)	5 (4·00)	.. ..	7 (6·31)	4 (2·61)	4 (4·35)	1 (1·43)	6 (4·54)	.. ..
42·5	59 (55·15)	10 (9·18)	12 (9·60)	9 (5·77)	12 (10·81)	21 (13·73)	7 (7·61)	5 (7·14)	16 (12·12)	.. ..
47·5	9 (8·41)	36 (33·03)	50 (40·00)	60 (38·46)	14 (12·61)	71 (46·40)	15 (16·30)	12 (17·14)	26 (19·70)	.. ..
52·5	.. ..	31 (28·44)	36 (28·80)	43 (27·56)	28 (25·23)	41 (26·80)	35 (38·04)	18 (25·71)	34 (25·76)	.. ..
57·5	.. ..	14 (12·84)	5 (4·00)	12 (7·69)	19 (17·12)	6 (3·92)	13 (14·13)	10 (14·29)	4 (3·03)	.. ..
62·5	1 (0·93)	5 (4·59)	1 (0·80)	.. ..	2 (1·80)	.. ..	1 (1·09)	1 (1·43)	.. ..	.. ..
Total ..	107 ..	109 ..	125 ..	156 ..	111 ..	153 ..	92 ..	70 ..	132 ..	72 ..
Maximum	60·5	65·0	62·0	60·0	64·0	59·0	62·0	61·0	60·0	21·0
Minimum	5·0	22·5	16·0	21·0	22·0	27·0	23·0	3·0	5·0	3·5
Mean	37·17	48·23	45·66	44·87	44·79	47·14	46·58	37·14	34·47	9·44
S.D,	12·17	8·74	9·37	10·48	11·00	6·10	10·25	21·22	15·52	4·32
S.E.	1·78	0·84	0·84	0·84	1·04	0·49	1·07	2·54	1·70	0·51

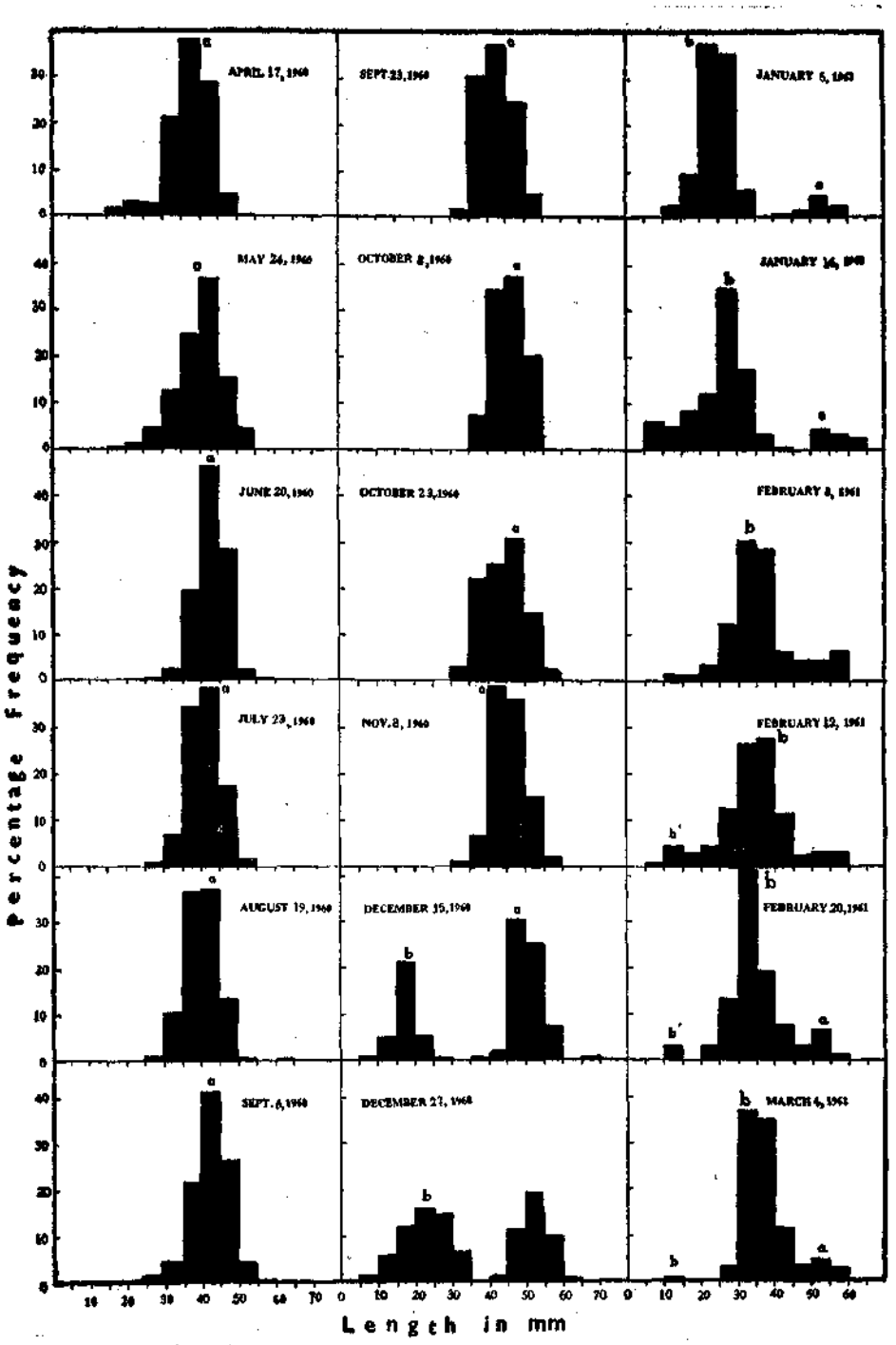


FIG. 18. Size-frequency distribution of *Solen kempi*.

place in the same month of the previous year. It may be seen that the same brood has grown to a modal size of 52·5 mm. by the 27th December as indicated in Fig. 18. The samples in the month of December 1960 also show new arrivals of the fresh brood ranging from 7 mm. onwards which should have been the result of active spawning in about October 1960. This fresh brood has attained a modal size of 17·5 mm. (*b*) by 15th and 22·5 mm. (*b'*) by 27th December 1960, the average growth being about 11 mm. per month. Earlier it has been stated that from October 1959 to April 1960 the clams had shown an average increase of 6 mm. per month and the higher rate of growth observed here in the first two months is what is normally expected in any growing population.

In the samples collected on 5th January 1961 there are two distinct groups. The larger one has a mode value of 52·5 mm. (*a*), the minimum size being 43 mm. and the maximum 60 mm. The smaller group has a mode value of 22·5 mm. (*b*) as in the previous month. In samples of January and February 1961 there is a reduction in the numbers of larger clams represented by their mode values of *a*. The smaller group represented by mode *b* shows an increase to 27·5 mm. by January 16th and 32·5 mm. by February 3rd. From a small mode of *b'* in January to April 1961 there is an indication that the younger clams are still entering the population subsequent to the peak spawning of October-November 1960. By about February to April there is usually an active fishing for clams in the locality which accounts for a gradual elimination of the larger clams in these months. On 2nd April 1961 the mode value of *b* is 37·5 mm. which is the same as for the corresponding month of the previous year for the group *a*. By 24th April 1961 the group *b* which is about 7 months old has attained a modal size of 42·5 mm. and the residual members of group *a* which is about one year and seven months old are at 62·5 mm. The individuals resulting from late spawning of 1960–61 season are spread out between 5 and 25 mm. with a small mode at 7·5 mm. By 19th May 1961 the group *b* shows an increase of 5 mm. in the mode value, but in the subsequent months of June to September it does not show any increase, the season being apparently unfavourable for growth, as in the case of group *a* for the corresponding months of the previous year. However, the sample for the month of August appears to be defective as it shows the mode value of *b* at 52·5 mm., with a difference of 5 mm. from the samples of July and September 1961. In the month of October 1961 the group *b* has a mode value of 52·5 mm. It has just completed one year and entered its second year of life. The younger clams which are the result of late spawning in 1960–61 season have grown rapidly and

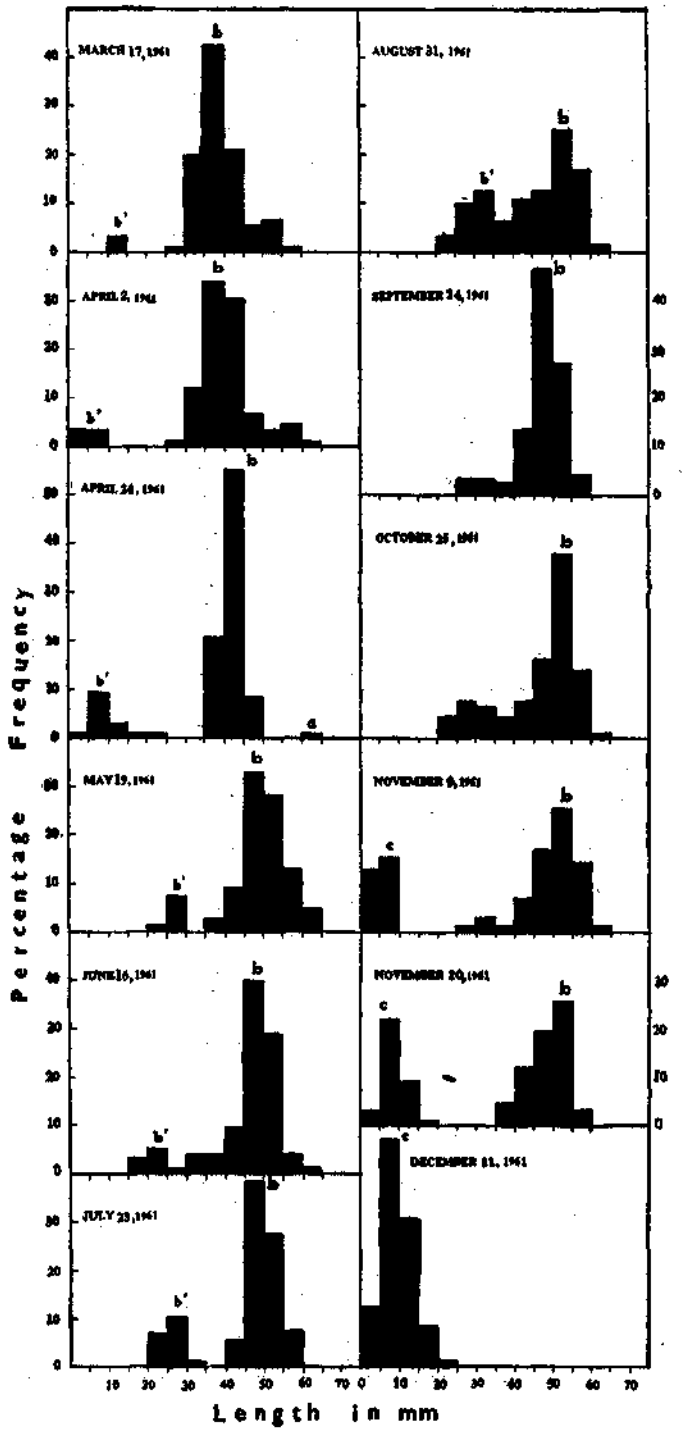


FIG. 19. Size-frequency distribution of *Solen kempi* (*continued*).

have merged with the older ones; yet, a small mode at 22·5 mm. representing the group *b'* is seen in the month of October 1961.

In the graphs for November 1961 the mode shows the same value as in October. There is a large number of very young individuals between 5 and 16 mm. with the mode value at 7·5 mm. entering the population, thereby showing, as in the earlier years, that there has been spawning in about the end of October 1961. The sample for December 1961 shows only the smaller individuals in large numbers collected from the deeper region close to the low watermark. Collections where bigger clams occurred in abundance were not made. Although the sample is defective, the fresh arrivals as a result of October-November spawning show in this month a size range of 3·5 to 21 mm. with a mode value at 7·5 mm. This distribution follows more or less the same pattern as in November 1961 except for the occurrence of a little older forms also in the latter.

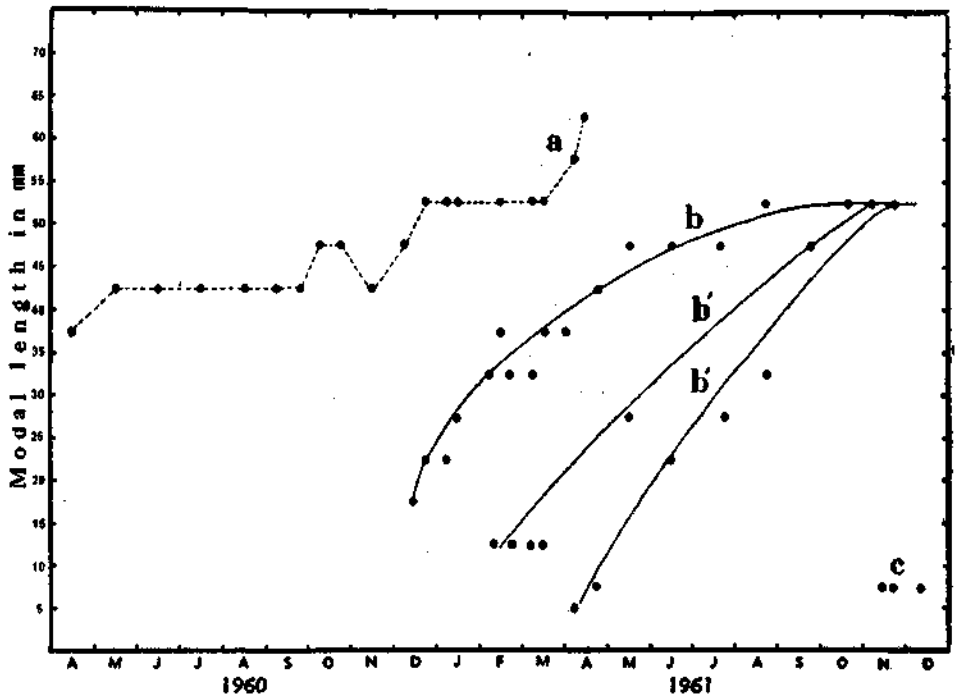


FIG. 20. Mode values of the samples of *Solen kempi* during different months.

It may be seen that subsequent to the spawning of the adult clams in October-November time, the young ones resulting therefrom attain an average length of 37·5 mm. in about 6 months showing an average growth

rate of about 6 mm. per month. The growth rate in the first three months appears to be yet greater, being up to about 11 mm. per month. Growth rate of clams after the first six-month period seems to be very low. When the clams are about one year old they attain an average length of 47·5 to 52·5 mm. which gives an average rate of growth of about 4 mm. per month. The total growth in the first six months of the second year of their life appears to be about 15 mm. (62·5–47·5), thus giving an average growth rate of 2·5 mm. per month. The maximum size noted in the samples is 66 mm. which appears to have been attained by the clams in the second year of their life.

Figure 20 shows the mode values of clams falling under different size groups in samples examined for the period. Those showing a progressive increase have been connected by lines. They fall into three distinct groups of *a*, *b* and *c* and are the result of spawning activity in successive periods as explained earlier. In the earlier part of their lives the clams in the samples show more than one mode because of the prolonged spawning activity resulting in the young appearing in successive batches.

LENGTH-WEIGHT, LENGTH-BREADTH (HEIGHT) AND LENGTH-THICKNESS RELATIONSHIPS

In the months in which clams of all sizes ranging from a few millimeters to the largest ones were available in the environment, they were obtained and preserved in formalin. Linear measurements in the antero-posterior direction for length, in dorso-ventral direction for breadth or height and from side to side in the broadest region for thickness were measured using a sliding vernier calipers. The formalin preserved clams were wiped dry on blotting-paper before their weights were taken. The larger clams were individually weighed but the smaller ones measuring the same length group were weighed together and the average weight of the individual members was calculated.

For the purpose of length-weight relationship a total 416 clams were taken. They were arranged in size groups of 5 mm. range against their respective average weights (Table III). From the observed measurements by applying the formula $W = AL^{\alpha}$ the calculated weights have been derived. It was found that $\log W = -4 \cdot 5467 + 2 \cdot 9130 \log L$ or $W = 0 \cdot 00002840\ L^{2 \cdot 9130}$ where L and W represent length and weight respectively. A curve has been fitted to the calculated weights as shown in Fig. 21. The observed average weights have been shown as dots. It may be seen that there is a fairly close

agreement between the observed average weights and the corresponding calculated weights for individuals falling under different length groups.

TABLE III

Showing the length-weight relationship of Solen kempi

Size groups (length in mm.)	No. of clams	Average length in mm.	Average weight in gm.	Calculated weight in gm.
7·5	9	8·61	0·011	0·015
12·5	17	13·15	0·054	0·052
17·5	37	17·81	0·175	0·125
22·5	25	23·40	0·333	0·277
27·5	46	28·08	0·499	0·470
32·5	47	33·05	0·772	0·756
37·5	61	37·89	1·191	1·126
42·5	61	44·35	1·589	1·781
47·5	56	47·66	2·150	2·196
52·5	37	52·39	2·852	2·893
57·5	13	57·04	3·314	3·708
62·5	5	62·30	4·208	4·794
67·5	2	66·00	5·930	5·669

In a similar manner the relationships between length-breadth and length-thickness have been determined (Table IV, Fig. 22). The formula for length-breadth relationship is $Y = 0{\cdot}7826 + 0{\cdot}1565\,X$ (X is length and Y breadth) and that for length-thickness relationship is $Y = -0{\cdot}0075 + 0{\cdot}1282\,X$ (X is length and Y thickness). From the foregoing data there is an indication that the shape and the general profile are almost constant at all stages of growth.

AGE AT SEXUAL MATURITY AND PERIOD OF SPAWNING

From every sample about 50 clams representing all sizes were examined microscopically for their gonadal condition. In the months when young clams occurred a greater proportion of them was carefully scrutinized to

ascertain the size at which sex differentiation took place and also the size at sexual maturity.

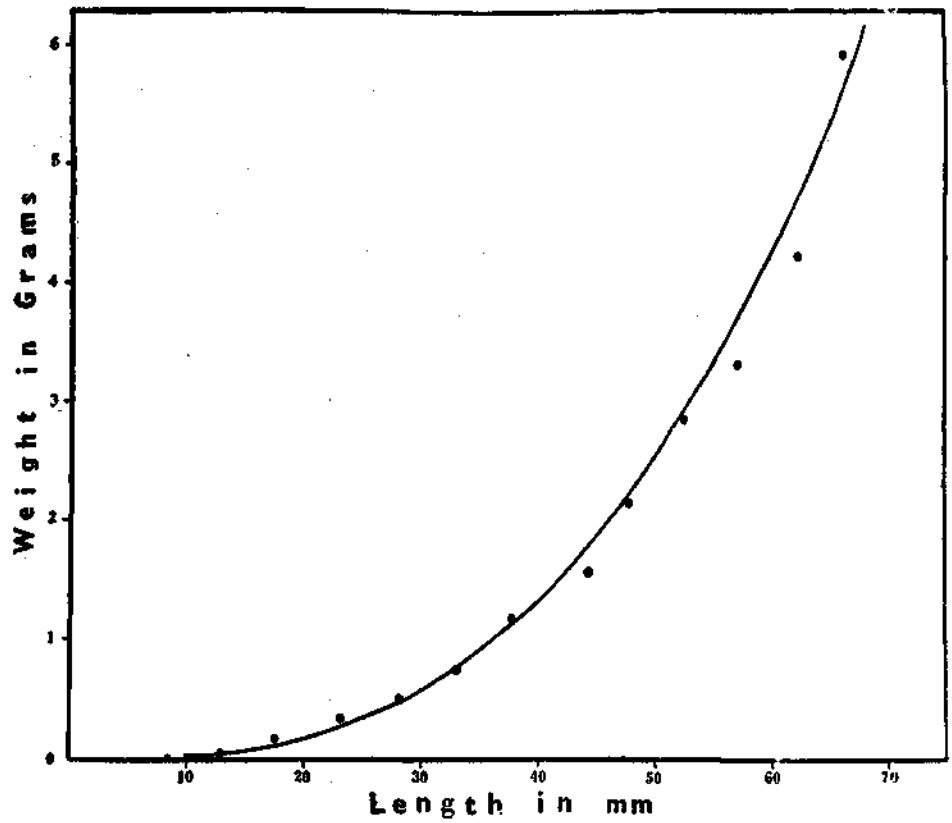


FIG. 21. Length-weight relationship in *Solen kempi*.

In individuals measuring 14·5 mm. the male follicles were clearly noticed with a few spermatocytes and in those measuring 17 mm. and above the development of the follicles was comparatively greater with clearly formed spermatozoa. In case of females the earliest indication of sex by the presence of oocytes in the follicles was observed in clams 16·5 mm. long. In slightly higher size of 20·5 mm. and above some developing ova were clearly noticed. Sexually ripe individuals of males and females were met with in all sizes over 30 mm. in length. As the average rate of growth is about 6 mm. per month in the earlier half of the first year in the life of the clams, it appears that the individuals attain sexual maturity when they are five months old.

During the period of twelve months from April 1960 to March 1961 the gonadal condition of the adult clams measuring 30 mm. and above has been observed as follows:

April and May.—The gonadal follicles in both sexes were shrunk and varying amounts of residual sperms and ova were met with in them.

June, July and August.—The gonadal follicles in both sexes were very much shrunk; the residual reproductive elements when present were comparatively fewer than in the earlier months; in some, sexes were indistinct as the gonad has passed into a state where the residual reproductive elements were completely absorbed and the lining germinal epithelium of a few small follicles bore only a small number of cells of indeterminable sex. Towards August the proportion of individuals of indeterminate sex was greater than in the earlier month and some with proliferating gonads were also met with.

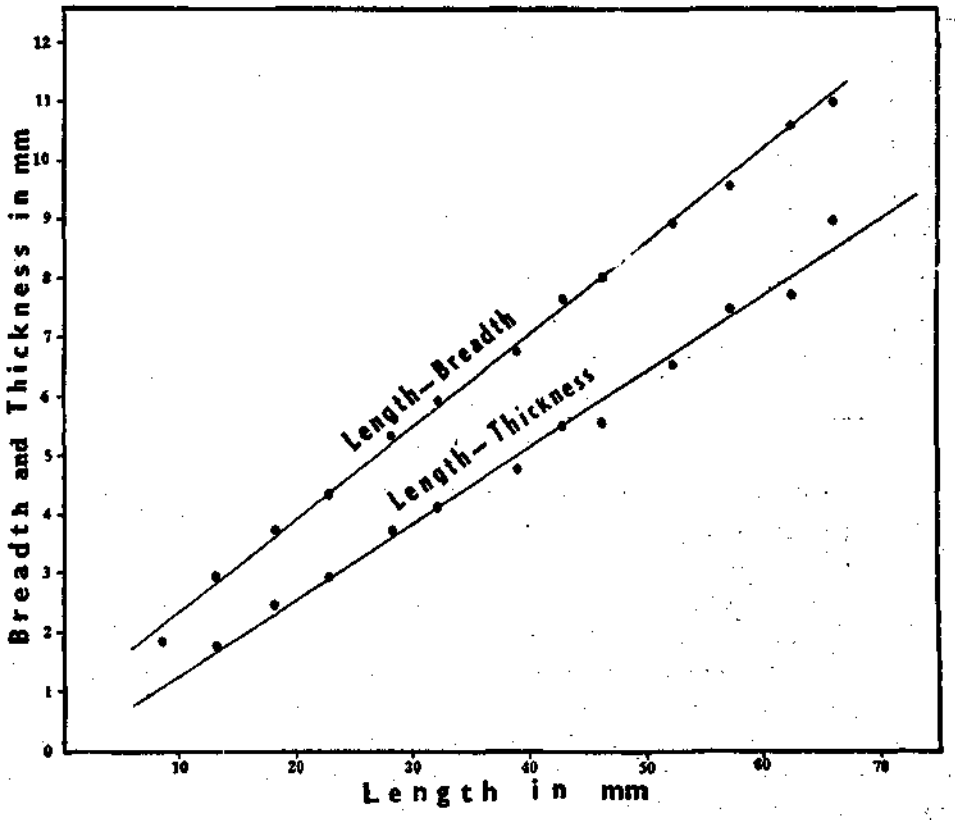


FIG. 22. Length-breadth and length-thickness relationships in *Solen kempi.*

September.—In all individuals examined, the gametogenetic activity was rapid. Spermatocytes and oocytes were numerous in the res-

TABLE IV

Showing the length-breadth (height) and length-thickness relationship of Solen kempi

Size groups (length in mm.)	No. of clams	Average length in mm.	Average breadth in mm.	Calculated breadth in mm.	Average thickness in mm.	Calculated thickness in mm.	Av. length / Av. breadth
7·5	7	8·564	1·821	2·123	..	..	4·70
12·5	30	13·333	2·933	2·869	1·767	1·702	4·55
17·5	30	18·167	3·750	3·626	2·491	2·322	4·84
22·5	30	22·950	4·383	4·374	2·916	2·935	5·24
27·5	30	28·167	5·300	5·191	3·717	3·604	5·31
32·5	30	32·200	5·900	5·822	4·108	4·121	5·46
37·5	30	38·950	6·783	6·878	4·775	4·986	5·74
42·5	30	42·683	7·625	7·462	5·466	5·464	5·60
47·5	30	46·100	8·033	7·997	5·523	5·903	5·74
52·5	30	52·333	8·983	8·973	6·566	6·702	5·83
57·5	30	57·100	9·583	9·719	7·466	7·313	5·96
62·5	5	62·400	10·600	10·548	7·700	7·992	5·89
67·5	1	66·000	11·000	11·112	9·000	8·454	6·00

pective sexes; fully formed sperms in large numbers and developing eggs at various stages of formation were met with; the gonadal follicles were fairly large in all.

October and November.—In the beginning, gonads in both sexes were full with ripe reproductive elements and towards the later part some individual members had shown partially spent condition.

December and January.—The gonads were in partially spent condition in most cases and with primary reproductive elements indicating gametogenetic activity in some.

February and March.—The gonads were mostly flabby, their follicles containing varying but limited numbers of residual reproductive elements showing spent condition.

In the following period up to December 1961 the gonadal condition was observed to be the same as that for the corresponding months of the earlier period, except for a slight delay in the commencement of the gametogenetic activity in the year 1961. In 1960 active proliferation of the reproductive cells appeared in August but in 1961 it appeared only in September.

From the above observations it appears that about late October or early November spawning commences, that in the succeeding months till January not only there is fairly vigorous spawning activity but also replenishment by fresh batches of eggs arising out of a spurt of gametogenetic activity and that spawning extends till about the end of March. The above observations have been corroborated by the occurrence of very young clams recorded in months immediately following October-November period till about April.

Density of Populations

From areas A and B (Fig. 16) which mark the extreme ends of the *Solen* beds all clams occurring in one square meter area were collected once a month to note the fluctuations in the density of clams present in the beds. The immature and mature individuals were grouped together separately both for A and B and shown in Table V. It may be seen that the number of clams in a square meter area in May to August for immature ones was low or nil and for mature ones high; in September to November for immature ones nil and mature ones low; in December-January for immature ones fairly high and mature ones low; and in February to April for immature ones low and mature ones high.

In both areas A and B the general fluctuation trends are the same. The relative abundance of the immature and mature clams in different months is almost the same as shown by the size frequency distribution of the larger random samples obtained in the corresponding months. The low density of adult clams from September to November is due to elimination by fishing in earlier months. The presence of a large number of smaller ones in December-January is the outcome of spawning activity in October-November period as explained earlier. The reduction in younger clams in March-April is due to spawning activity being almost over and also to a rapid rate of growth of young ones to attain the adult size in the period. The data show a slightly higher numerical abundance of clams in area B than in area A except for May 1960. In a subsequent period also these areas show almost the same trends. For areas A and B the numbers of clams per square meter in May 1961 are 38 and 50, in June 43 and 56, in July 31 and 42 and in August 12 and 20.

It may be mentioned that as sexual maturity is attained at a minimum length of 30 mm. all of that size and above have been considered mature and all below immature.

TABLE V

Showing the density of clams in areas A and B per square meter

Months	Immature clams		Mature clams		Average of all clams per square meter*
	Area A	Area B	Area A	Area B	
1960					
May ..	2	5	52	46	52
June ..	..	..	54	61	57
July ..	No data	..	No data	18	18
August ..	..	2	37	43	41
September ..	..	..	11	19	15
October ..	..	..	8	16	12
November ..	..	..	9	11	10
December ..	25	30	6	8	34
1961					
January ..	29	37	5	7	39
February ..	9	7	20	33	34
March ..	1	2	37	49	44
April ..	..	1	25	44	35

* No fraction of a clam included in calculating averages.

FOOD AND FEEDING

As in all bivalves there is in *S. kempi* a ciliary mode of feeding, the ingoing current carrying with it into the mantle cavity minute organisms and other particulate matter in suspension from the environment and these being entrapped in mucus over the gills and wafted by their cilia to the labial palps and from there in a similar manner into the mouth.

During the period of observations from each of the monthly samples a dozen of the adult clams were examined for their stomach and intestinal contents. Whilst the region of the stomach is very small, that of the intestine

is long and coiled. Very little of the food items from the stomach and fair amounts of the same from the intestinal region were observed.

A few blue-green algae, diatoms in abundance, dinoflagellates occasionally, some foraminiferan and radiolarian shells, spicules of unrecognisable origin, very few small harpacticoid copepods, detritus in good amounts and fairly often grains of sand comprised the stomach and intestinal contents. It has been found that invariably diatoms and detritus constituted the essential items of food. The blue-green algae represented by *Microcystis* were frequent but not abundant. The diatoms were represented by *Cyclotella meneghiniana, C. striata, Coscinodiscus jonesianus, C. marginatus, C. rothii, C. excentricus, C. centralis, C. apiculatus, C. sublineatus, C. gigas* and *C. concinnus* of the family Coscinodisceae; *Leptocylindrus* sp., and *Rhizosolenia alata* of the family Solenieae; *Chaetoceros coarctatus* and *C. denticulatus* of the family Chaetocereae; *Hemiaulus hardmannianus* of the family Euodieae; *Licmophora abbreviata, Thallassionema nitzschioides, Thallassiothrix longissima* and *T. frauenfeldii* of the family Fragilarioideae ; *Cocconeis littoralis* and *Achnanthes stromii* of the family Achnanthoideae; *Mastogloia exilis, M. minuta, Gyrosigma balticum, Pleurosigma* sp., *Diploneis weissflogii, D. puella, D. smithii, Navicula approximata* and *Amphora* sp. of the family Naviculoideae; *Bacillaria paradoxa* and *Nitzschia* sp. of the family Nitzschiaceae; *Campylodiscus* sp. of the family Surirellaceae and *Biddulphia sinensis* of the family Biddulphieae.

Of the above diatoms *Coscinodiscus concinnus, Chaetoceros coarctatus, Thallassiothrix longissima* and *Diploneis* spp. were found common and the rest fairly frequent except *Hemiaulus hardmannianus, Amphora* sp. and *Leptocylindrus* sp. which were very rare among the contents of the alimentary tract. Bacteria, ciliates and some nannoplankters might be taken by the clams along with the decaying organic matter comprising the detritus, but the presence of these groups of individuals, being easily digestible, was not recognised among the food components obtained from the alimentary tract. Sand of very fine grain is always found in the shallow waters due to the constant disturbance of the bottom soil by wave action and this along with the foraminiferan and radiolarian shells, spicules, etc., often found at the substratum may accidentally find an entry into the digestive tract in most of the bottom living filter feeders although they may not serve a nutritive purpose.

Fishery

Solen kempi from Gav-khadi supports but a minor fishery of some local importance only. The fishery usually is at its best from February to May,

moderate from June to September and poor or altogether absent in some months from October to January. In the summer months of 1961, when the fishing was at its height, the highest number of clam fishers was 57 and at other times the usual number was about 30 on an average in summer, about 15 in monsoon and about 5 in the post-monsoon and winter months. The availability of the clams in greater quantities coupled with favourable weather conditions prompts the fishers to go for fishing in large numbers and on as many days as possible in summer months, depending upon the occurrence of low tides during daytime. In monsoon months, although the weather conditions are unfavourable and the availability of the clams is also in moderate quantities there is still a good inducement for fishing as the demand for them is high due to non-availability of fish because of cessation of general fishing activities save for the operations of a few bag-nets and cast nets in the creeks during the period. The very low fishing activity for clams in the post-monsoon and the winter months is because of considerable reduction in the number of adult clams occurring in the area.

Fishing is done exclusively by women and small girls belonging to a Hindu community, known as 'Bhandaris', the men-folk of which, in general, take mostly to agriculture or fishing as their profession. The clams are fished during daytime at low tides. Their presence in the burrow is recognised by the holes they leave on the surface of the soil, one for each individual clam for the protrusion of the siphons, through which at times they eject jets of water. When clams are thus spotted, they are dug out of their burrows by means of a knife with a wooden handle and a steel blade, 1·5 cm. broad and 15 cm. long, sharp and pointed at its free end. The removal of the clams from the burrows is often quickly accomplished for they have the habit of burrowing to deeper and deeper regions rapidly to escape being caught when they are sought after by the digger. They are collected in bamboo baskets with a diameter of 10 to 15 cm. and a height of 10 to 18 cm. As the meats are small in young clams those below 30 mm. are never collected.

The quantity fished is barely sufficient to meet the local demand and is not saved for profit for marketing elsewhere, due to lack of adequate transport facilities and also because the consumers, in general, prefer oysters and *Meretrix* to *Solen*. Much of the catch is, therefore, utilised for domestic consumption by the fishers and a part of it is sold as bait for longline fishing. In preparing the clams for food, the shells are removed and their meats are squeezed and washed. They are fried in oil with coconut paste, condiments and salt or made into curries using the same ingredients. Part of the day's

catch is saved in fresh condition to be cooked and served at the next day's lunch.

The longline fishermen find *Solen* more suitable than other clams because in the former the shells are more easily removable and the meats are firm on the hooks and not too soft to drop down when the line is cast. The shells being thin and delicate are not used for any purpose, not even for burning them into lime.

Of the commercial catch in each month a small sample was obtained from the fishers to study the frequency distribution of the different size groups. The samples were combined for each season, analysed and presented in Table VI for a period of one year from June 1960 to May 1961. It may be seen that the size groups, representing more than 15% of the number of clams, fall into one large group between 37·5 and 47·5 mm. totalling to 91·6% in the monsoon months of June to September; into a similar group between 42·5 and 52·5 mm. totalling to 82·9% in the post-monsoon months of October and November; into two definite groups, one between 32·5 and 37·5 mm. forming 24·1% and the other between 47·5 and 52·5mm. comprising 36·3% in winter months of December to February; and into one group between 32·5 and 37·5 mm. forming 71·8% in the summer months

TABLE VI

Showing the composition of the commercial catch of Solen kempi *in different seasons*

Size groups (Length in mm.)	Monsoon (June, July, Aug. and Sept.)			Post-Monsoon (Oct. and Nov.)			Winter (Dec, Jan. and Feb.)			Summer (March, April and May)		
	No.	(%)	% × Av. Wt. (gm.)	No.	(%)	% × Av. Wt. (gm.)	No.	(%)	% × Av. Wt. (gm.)	No.	(%)	% × Av. Wt. (gm.)
32·5	106	(5·8)	4·5	10	(1·8)	1·4	157	(29·1)	22·5	73	(15·0)	11·6
37·5	520	(28·7)	34·2	74	(13·6)	16·2	93	(17·2)	20·5	141	(29·0)	34·5
42·5	745	(41·1)	65·3	174	(31·9)	50·7	37	(6·9)	11·0	135	(27·8)	44·2
47·5	396	(21·8)	46·9	188	(34·5)	74·2	89	(16·5)	35·5	61	(12·6)	27·1
52·5	44	(2·4)	6·8	90	(16·5)	47·1	107	(19·8)	56·5	46	(9·5)	27·1
57·5	2	(0·1)	0·3	9	(1·7)	5·6	51	(9·5)	31·5	23	(4·7)	15·6
62·5	1	(0·05)	0·2	..	..	..	5	(0·9)	3·8	7	(1·4)	5·9
67·5	..	..	..	..	..	..	1	(0·2)	1·2	..	..	..
Total ..	1814	..	158·2	545	..	195·2	540	..	182·5	486	..	166·0
Mean size		41·84	..		45·26	..		43·19	..		42·12	..
Mean of % × Av. Wt.			1·582			1·952			1·225			1·660

of March to May. In general, clams obtained in summer and monsoon months are of comparatively smaller size than those obtained in the post-monsoon and winter months. For each season the weight of 100 clams is obtained by multiplying the average weight in each size group (*vide* Table III) with the percentage frequency of the sample; the weights thus obtained are 158·2 gm. for monsoon, 195·2 gm. for the post-monsoon, 182·5 gm. for the winter and 166·0 gm. for the summer seasons. Because of the larger clams being obtained in greater numbers in the winter and post-monsoon months, their total weights for the respective samples are greater than those of similar samples in the other two seasons. Fishing intensity, however, has no relation to comparatively greater abundance of larger clams in certain seasons. As stated earlier, favourable weather conditions, occurrence of denser population in the environment and the prevailing demand determined the intensity of fishing in different seasons.

An approximate estimate has been obtained of the extent of the yield of clams from the region for a twelve-month period during 1960–61 on the basis of the number of days and the number of persons engaged in fishing and average catch per head of clams fished. By the monthly and occasionally fortnightly observations on the spot, supplemented by the information furnished by the fishers, it was found that on an average 30 fishers at 3 lb. per head for 61 days had collected 5,490 lb. of clams from February to May; 15 fishers at 2 lb. per head for 44 days collected 1,320 lb. in June to September; and 5 fishers at 1 lb. per head for 31 days collected 155 lb. from October to January, giving a total of 6,965 lb. worth Rs. 2,089·50 at the prevailing rate of 30 P. per lb.

General Considerations

Taxonomy.—In the foregoing account are given only those species of *Solen* which are known to occur in Indian waters and whose systematic position has been well defined by the taxonomic characters available from the authentic records of different scientific workers. There are a few like *S. corneus* Lamarck (*vide* Hornell, 1949) reported from the Indian waters but without any account of their diagnostic characters. The species of *Solen* are distinguishable from one another by the length-height ratios of the shells, the position of the hinge teeth, the colour markings on the periostracum, the shape of the valves and the location and the configuration of the adductor muscle impressions. Among the soft parts, the shape of the foot, the nature of the siphons, the structure of the labial palps, the course of the intestinal loop have some characteristic value. There is so much

overlapping of characters between one species and another that correct identification of the forms often becomes very difficult. It is worthwhile noting here that some of the Chilka Lake members of the genus were at first supposed to be juveniles of *S. truncatus* Wood, but were subsequently found to be full-sized sexually mature individuals and were described under two separate new species, *i.e.*, *S. kempi* and *S. annandalei* (Preston, 1915); similarly another form from the same locality was originally referred to *S. fonesi* Dunker but later described as *Neosolen aquae-dulcioris*, a new species under a new genus, but now known under the genus *Solen*. Often in casual collection of shells washed ashore one comes across with forms which cannot be assigned to any of the species described here, a fact which warrants a detailed investigation of the systematics of the members of the genus. When forms other than those given here are observed, if they are reported with definite descriptions, it would immensely help to add to our knowledge of the members of the genus.

Environment.—*S. kempi* has first been recorded from near the mouth of the Chilka Lake and later from Satpara and Nalbano island which also are situated not far from the mouth of the lake where, to a large extent, marine conditions prevail. In Madras dead shells of the species were found on the beach between Ennur backwater and the sea (Gravely, 1941). In Gav-khadi, the *Solen* beds are adjoining the creek which communicates with the open sea all through the year. In the monsoon the salinity falls low, but it does not remain steady for long as the waters are subject to tidal rhythm. From these observations it appears that the species, in general, inhabits such regions as the bays, nearby areas to the open sea, such as creeks and mouths of backwaters where the waters are fairly calm and mostly under marine conditions, but occasionally subject to fresh-water influence. It is scarcely found in such backwater regions which are completely cut off from the sea for prolonged periods.

In Adyar backwaters Rao (1952) has observed that while *Catelysia opima* occurs in areas close to the bar where marine conditions prevail, *Meretrix casta* is found extending from near the bar to regions far high up the river mouth. *Donax* occurs purely under marine conditions in sandy surf (Nayar, 1955). It may thus be seen that even when several of clam species occur in one and the same geographical area, there is a distinct zonation in respect of each species although sometimes the zone of one species overlaps the zone of another species to some extent. In a region where *Solen kempi* and *Catelysia opima* occur the zone of the former is much nearer towards the sea than that of the latter.

Growth rate.—The rate of growth in the shellfish is dependent to a large extent on the environmental conditions. In *Catelysia opima* (Rao, 1952) studied from Adyar estuary growth seems to be confined to a period from January to July which is marked by a gradual increase in salinity and almost totally arrested from August to December when there is a fall in salinity. In some clams it has been observed that growth is slackened due to certain internal factors as low metabolic activity due to spawning. Thus Abraham (1953) finds in *Meretrix casta* from the same environment, retardation of growth at least twice a year, once during September to November when there are heavy rains and consequent low salinity conditions and again from February to March which coincides with the spawning period of the clam. Rao and Nayar (1956) observe in the oyster, *Crassostrea madrasensis* different rates of growth in different periods of the year which appear to be due to the widely fluctuating environmental conditions. It has been found that the growth rate of the oyster spat and yearlings is adversely affected when very high or very low salinity conditions continue for prolonged periods in the environment, as it happens when the sand-bar cuts off communication of the estuary with the sea.

In *Solen kempi* from Gav-khadi area growth of the young ones, resulting from October to November spawning, is rapid up to May when the salinity values are high, but almost nil from June when the salinity records are the lowest as revealed by data presented in Table I for the years 1960 and 1961. It may also be seen that the increase of salinity in the waters of the environment by about October is followed by revival of growth in the clams. Whether the low salinity of the waters in the environment has a direct adverse effect on the growth rate or indirectly brings about a state of physiological imbalance so as to slacken or arrest the growth of the clams is a matter which needs careful investigation which is beyond the scope of the present study.

Spawning.—It is worthwhile comparing the breeding periodicity of the different bivalve species studied in India from the marine and brackish water environments. In *Catelysia opima* from Adyar estuary (Rao, 1952) the spawning period is short commencing from late December and lasting throughout January, spawning time being preceded by the opening of the bar and the mixing of sea-water with the estuarine water. *Meretrix casta* from the same environment appears to breed throughout the year, but the peak of the spawning activity is attained in certain months only (Abraham, 1953). In *Crassostrea madrasensis* Rao (1951) has found under backwater conditions sexual activity being restricted to November-December followed by a supplementary spawning in about March-April, induced probably by

optimum salinity conditions, and under marine conditions the same species breeding all through the year but with two peaks of activity, once in about November-December and again about May which correspond to low salinity and high temperature conditions prevailing in the environment in the respective periods. Nayar (1955), in *Donax cuneatus*, has observed that the spawning lasts from January to end of April during which there is a gradual increase in salinity but in the period immediately preceding it the salinity has been very low.

In *S. kempi* it may be noted that spawning is fairly prolonged commencing in October-November and lasting up to about end of March which period is marked by a gradual increase in salinity in the waters of the environment. Sexual maturity is attained when the clams are about five months old, but no spawning seems to take place till they are one year old. In *Catelysia opima* (Rao, 1952) also it has been noticed that although the sexual maturity is attained in clams at about the end of the fourth month, the first spawning does not take place till they are one year old. After the first sexual maturity why the ripe reproductive elements are retained in the gonad for a prolonged period and what may be the factors which contribute to initiating the spawning activity are not understood.

Nutrition.—In *S. kempi* in the present investigation what all recognisable elements were found in the stomachs and intestines of the preserved clams have been identified and listed. It has been found that certain species of diatoms and detritus were the most common. This excludes certain minute nannoplanktonic organisms, bacteria, etc., which are always found in the environment, but not easily recognisable from the analysis of the preserved material. The nutrition of the bivalves in general appears to be derived from very minute particles such as detritus from the disintegrated plant or animal matter, minute flagellates and other protozoans, very small diatoms and gametes of algae and of invertebrates, the larger organisms though present along with others being not digested but eliminated after their passage through digestive tract (Coe, 1945, 1947).

Density of populations.—In the present study no attempt was made to assess the natural rate of mortality of the clams in the beds. Dead clam shells were always found in large numbers. These might have been the result of natural mortality or the result of fishing in which some of the clams picked up by longline fishermen are opened up and used as bait, their shells being discarded on the beds where they occur. On no occasion were found appreciable numbers of dying or dead shells with meats still in tact. The

frequency of occurrence was considered in relation to the appearance of fresh arrivals after spawning or elimination of the old r ones due to fishing.

SUMMARY

The taxonomic characters of the species of *Solen* occurring in the Indian region, *viz.*, *S. lamarckii* Deshayes, *S. truncatus* Wood, *S. linearis* Spengler, *S. aspersus* Dunker, *S. aquae-dulcioris* (Ghosh), *S. kempi* Preston, *S. annandalei* Preston and *S. gravelyi* Ghosh have been described.

The environmental conditions of the *Solen* beds in Gav-khadi near Ratnagiri have been studied.

Growth rate of *S. kempi* has been estimated by the examination of random samples obtained at regular intervals of time for a period of 21 months from April 1960 to December 1961.

The clams appear to attain in the first six months of life, a length of 37·5 mm. with an average rate of about 6 mm. per month. Growth after the first six-month period is very slow. One year old clams show an average length of 47·5 to 52·5 mm.

Clams in the first six months of their second year of life show an increase of about 15 mm. The largest size of 66·0 mm. observed in the locality is presumably attained when the clam has been in the second year of its life.

Length-weight, length-breadth and length-thickness relationships have been studied.

All clams of both sexes, when they are 30 mm. in length and when they have completed five months of their life, are sexually mature. The seasonal gonadal condition of the adult clams has been studied. Spawning appears to commence in late October or early November and extend till end of March.

The low density of adult clams in September to November is due to elimination of most of them by fishing in earlier months. The density of small clams in December-January period which is very high is due to fresh arrivals after October-November spawning.

Detritus and minute diatoms are the most common items found in the stomachs and intestines of the clams.

The species supports a minor fishery at Gav-khadi. The fishery is at its best from February to May, moderate from June to September and poor or altogether absent from October to January. Fishing methods have been

described. The composition of the commercial catch has been studied. The extent of yield from Gav-khadi has been estimated.

ACKNOWLEDGEMENTS

The authors take the opportunity of expressing their gratitude to Dr.S. Jones, Director, Central Marine Fisheries Research Institute, for according permission and making available facilities for taking up the present studies outside their normal official duties. They express their sincere thanks to Shri S. K. Banerji, Senior Research Officer, Central Marine Fisheries Research Institute and Shri K. Krishna Rao, at present Assistant Research Officer, Central Institute of Fisheries Technology, for rendering all necessary help in the presentation of statistical data.

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