

## Production Ecology of a Tropical Sandy Beach at Benaulim, Goa

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Species composition, biomass and available food of the intertidal fauna were studied at monthly intervals. Fluctuations in the production of macrofauna were related to environmental stress and availability of food. In the premonsoon months (February-May), faunal diversity and biomass were maximum with a marked zonation on the beach. During monsoon (June-September), the beach was characterized by the presence of tidal migrants which could withstand changing sea conditions. Three feeding types, viz. feeders on plankton and suspended matter, deposit feeders and scavengers and predators, were represented. Annual requirement of carbon for the macrofauna was estimated to be 2574.4  $\mu\text{gC}/\text{m}^2$  transect. An attempt to understand trophic relationship indicated sufficient food from direct sources to meet the demand.

**E**COLOGY of sandy beaches with special reference to macrobenthic populations along the Indian coasts has been studied<sup>1-6</sup>. Earlier, seasonal changes in physico-chemical factors and macrofauna have been investigated. Some biological details of common intertidal populations have also been worked out from the Cochin, Shertallai and Goa beaches<sup>2,3,6</sup>. McIntyre<sup>7</sup> has reported meiofauna and macrofauna inhabiting the beaches near Porto Novo on the east coast. Physico-chemical and biological changes during 1 yr at Benaulim beach, Goa have been studied with a view to understanding the trophic relationship.

### Materials and Methods

Observations were made at favourable low tides from a fixed reference point selected near the supralittoral fringe of the beach to the water's edge at monthly intervals from July 1973 to June 1974. Water samples for oxygen, salinity, chlorophyll *a* (chl. *a*) and particulate organic carbon were analysed following standard methods<sup>8</sup>. Methods adopted for the collection of interstitial water samples were similar to those suggested by Pamatmat<sup>9</sup>. Macrofauna sampling was done by pushing a quadrat frame (0.1 m<sup>2</sup>) into the sand up to a depth of 10 cm from high water mark to water's edge at every 10 m interval, the enclosed sand was sieved using a 0.5 mm meshed screen. The animals retained were preserved in 5% formalin and their wet weights taken as biomass. Molluscs were weighed after their shells were removed. Sand was collected at different tidal levels for studying grain size<sup>10</sup> and organic carbon content<sup>11</sup>. Standard surveyor's techniques were employed to study the beach profiles on selected occasions.

### Results

*Physical and chemical conditions* — Benaulim (long. 73°50'E; lat. 15°15'N) forms a part of a long stretch of shallow sandy beaches interrupted by Mandovi and Zuari rivers on the north and river Sal in the south. Beach building takes place during February-

May and October-January when comparatively stable conditions prevail unlike during June-September when physical factors bring about changes which are reflected in the beach profiles and textural characteristics (Figs. 1a and b). Changes in beach profile, were maximum in July and August and in following months the return of a gentle slope was accompanied by a recovery of sediments by finer sands at the lower foreshore (Fig. 1b). Decrease in the mean grain size of sediments at all tide levels was noticed during the beach building period. All through the year sediments consisted mainly of alternating loose to fine sand (range 55 to 380  $\mu$ )

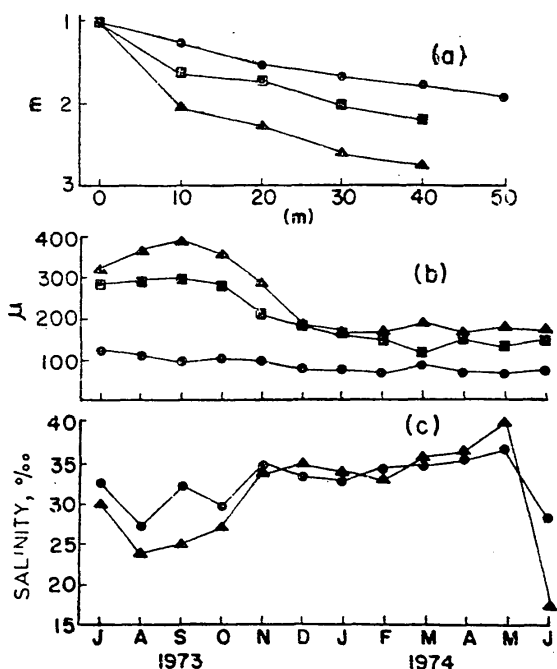


Fig. 1 — (a) Averaged beach profiles [ $\blacktriangle$ , monsoon;  $\blacksquare$ , premonsoon; and  $\bullet$ , postmonsoon]. (b) Textural diameter of the sediment [ $\blacksquare$ , postmonsoon;  $\blacktriangle$ , monsoon; and  $\bullet$ , premonsoon]. (c) Salinity of the surf water ( $\bullet$ ) and 10 m interstitial water ( $\blacktriangle$ )

at all tide levels; coarser fractions were associated with the wash zone.

Wave conditions during fair weather seasons indicated, in general, that the wave height remains below 1 m throughout the year except during monsoon. Fluctuations in salinity of surf water were not very marked except during monsoon with a building up period from October to May when values increased to 36.5‰. Likewise, interstitial water showed a similar trend except some higher values of 37.8‰ obtained during peak summer months. Rapid fall in the salinity values during monsoon may be due to heavy precipitation (Fig. 1c). Temperature of surf and interstitial water are shown in Fig. 2a. The variation in temperature was between 25° and 31.8°C for surf water and between 26.1 and 31.5°C for the 10 m interstitial water. Sand surface temperatures followed almost the same pattern as 10 m station in this beach since observations were carried in the morning hours. Surf oxygen values showed a fluctuating trend varying from 3.8 to 5.4 ml/litre (Fig. 2b). Values of interstitial water showed a peak in December and thereafter declined to almost 1.0 ml/litre. Water table depth at 10 and 20 m stations are shown in Fig. 2c. At lower stations, the depth was generally from sand surface to about 50 cm but at upper stations, it went below 70 cm. Availability of water table up to 75 cm depended mainly on porosity and elevation of the beach. Organic carbon in the sand was between 355 and 1500 µg/g (Fig. 3a). The values increased at all tide levels from October

onwards with peaks in December and January. During monsoon the values were generally low.

Surf chlorophyll values showed a peak in summer months (April-May) with values up to 9.108 mg/m<sup>3</sup> (Fig. 3b). Values in the following months particularly during monsoon were very low. Particulate organic carbon in the water column corresponded with chlorophyll peaks except during postmonsoon period. Decrease in surf chlorophyll and organic carbon coincided with low salinity and rainfall as observed by Ansell *et al.*<sup>1</sup>

*Beach fauna* — Distribution of major species found at Benaulim are presented in Fig. 4. Ghost crabs *Ocyropa ceraptothalma* Pallas and *O. cordimana* Fabricius were abundant above the high water mark and these were not sampled quantitatively for the study. The most abundant species found throughout the year was bivalve *Donax incarnatus* Gmelin and was present in large numbers specially during February with a density of about 7630 individuals/m<sup>2</sup>. *D. spiculum* Reeve showed a patchy distribution at this beach and occurred only in November and December. Other bivalves present sporadically were *Paphia textile* Gmelin and *Sunnetta scripta* Reeve along with *Donax* spp. in the mid tide level. *Gafrarium pectinatum* Linn. occurred at some stations in the low water in postmonsoon months and was absent during monsoon period. *Umbonium vestiarium* Linn. was the only gastropod found on this beach in abundance in September and March. Carnivorous polychaete *Glycera alba* Rathke was irregularly present in mid and lower parts of the beach. *Onuphis eremita* Aud. and Milne-Edwards was found almost throughout the year except April and June. Other polychaete inhabitants were *Nereis* sp. which was abundant in postmonsoon, and *Pisionidens indica* Aiyer and Alikunhi, which was sporadically present in small numbers. Cirrolanid isopods *Eurydice peraticis* Jones and *E. indicis* Jones were the most dominating species occurring with a density up to 8600 and 1860/m<sup>2</sup> respectively.

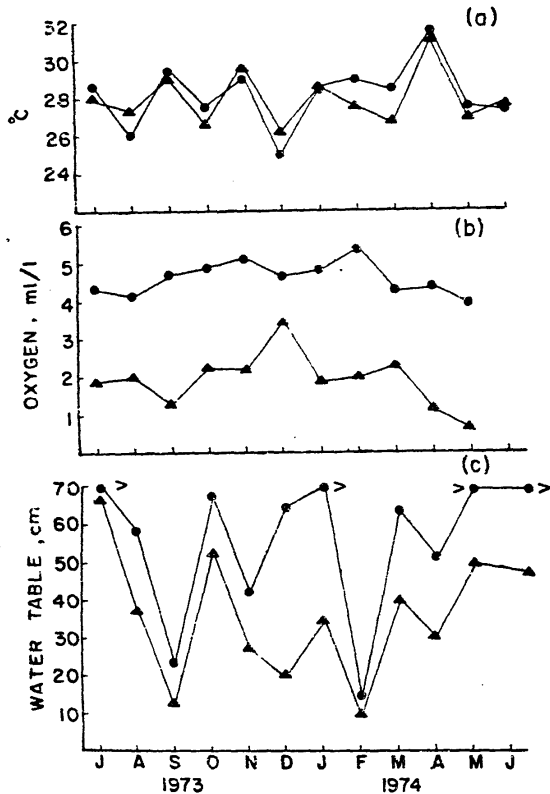


Fig. 2 — (a) Temperature of the surf (●) and 10 m interstitial water (▲). (b) Surf oxygen (●) and 10 m interstitial oxygen (▲). (c) Water table depth at 10 m station (▲), 20 m station (●). > indicates WT above 75 cm.

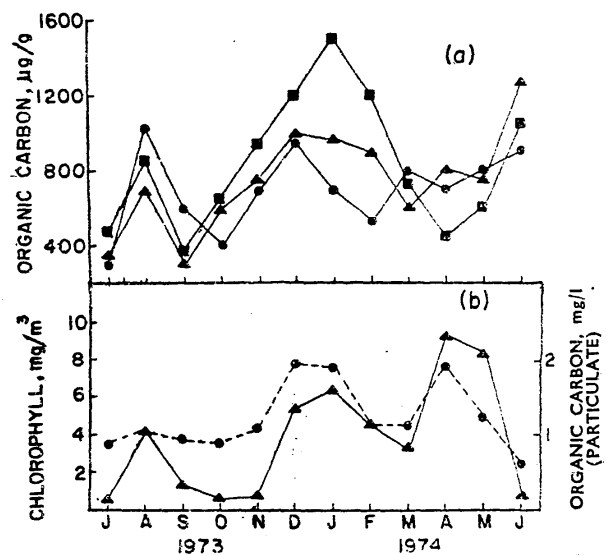


Fig. 3 — (a) Sand organic carbon at 3 tide levels [■, mid tide level; ▲, low tide level; and ●, high tide level]. (b) Surf chlorophyll *a* (▲) and particulate organic carbon (●)

Next to isopods, mysid *Gastrosaccus* sp. was abundant in September with 5100/m<sup>2</sup>. Mole crab *Emerita holthuisi* Sankolli was present in good numbers in wash zone and formed a major component of the fauna. Other decapods inhabiting wash zone included the crab *Philyra globosa* Alcock, hermit crabs *Diogenes custus* Fabricius and *Clibinarius padavensis* d'Man.

**Biomass**—Table 1 gives the biomass at individual stations sampled and its distribution. High values encountered at some stations were mainly due to the abundance of bivalves. As pointed out by Ansell *et al.*<sup>1</sup>, correct representation of biomass at any one station is difficult due to extreme mobility

of fauna and longshore migrations of species which tend to form discrete aggregation, specially mole crabs, bivalves and gastropods. To minimize these factors, a moderately correct representation could be achieved by combining the station biomass and making the calculations to represent as transect biomass. It can be seen from Fig. 5 that bivalves contribute the most followed by crustaceans, polychaetes and gastropods. Maximum total biomass of 2315 g/m<sup>2</sup> transect was observed immediately after the cessation of rains in November with a secondary peak in January coinciding with an increase in bivalves biomass. Crustaceans were next in order with negligible biomass during monsoon months showing a gradual build up in November with peak values by January. Polychaetes were poorly represented in monsoon months but showed a good recovery by January with 318 g/m<sup>2</sup> transect and a gradual decline in biomass values. Gastropods were represented by *Umbonium vestiarium* and their maximum biomass values reached 160 g/m<sup>2</sup> transect in November.

**Trophic relationships**—Three basic feeding types are represented in the beach fauna, viz. Scavengers

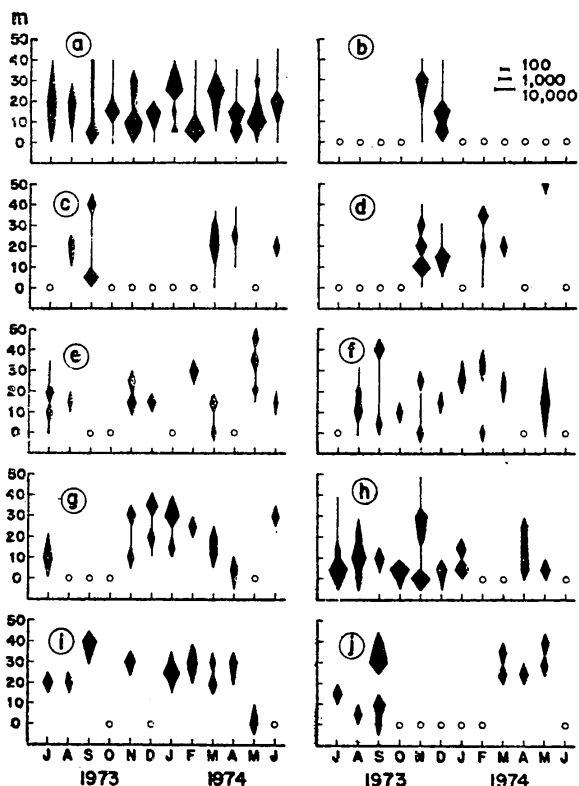


Fig. 4 — Distribution of fauna on the beach [a, *Donax incarnatus*; b, *D. spiculum*; c, *Umbonium vestiarium*; d, *Gastrosaccus pectinatum*; e, *Glycera alba*; f, *Onuphis eremita*; g, *Nereis* sp.; h, *Eurydice peratidis*; i, *Emerita holthuisi*; and j, *Gastrosaccus* sp.]

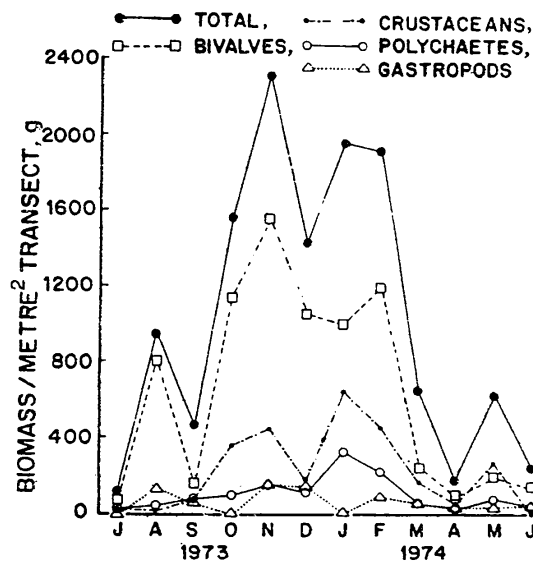


Fig. 5 — Biomass of dominant faunal groups in metre/ transect

TABLE 1 — BIOMASS RANGE AND DISTRIBUTION ON THE EXPOSED INTERTIDAL AREA OF THE BEACH

Month	Range in biomass g/m <sup>2</sup>	Stations seaward										
		0	5	10	15	20	25	30	35	40	45	50
July	2-41	2	26	36	12	41	—	—	—	—	—	—
Aug.	6.8-874.8	6.8	31	874.8	9.6	24	—	—	—	—	—	—
Sept.	16-248	205	248	16	—	—	—	—	35	—	—	—
Oct.	2.5-1340	2.5	12.8	72	1340	128	—	—	—	—	—	—
Nov.	20-1257	20	700	1257	105	29	180	27	—	—	—	—
Dec.	8-905	27	8	480	905	—	—	—	—	—	—	—
Jan.	25-980	—	25	38	830	980	85	—	—	—	—	—
Feb.	15-1303	57	1303	85	50	30	250	—	15	152	—	—
March	9.5-312	—	9.5	11.5	18	85	312	128	62	—	—	—
April	2-98	—	18	98	40	—	5	2	18	—	—	—
May	2-300	8.9	20	242	300	6	—	8	2	5	—	6.9
June	0-225	0	—	—	3.2	225	—	—	—	—	—	—

and predators, deposit feeders and feeders on plankton and suspended matter. Among predators, Ocypodid crabs scavenge on the beach and prey on burrowing fauna especially on mole crabs and bivalve molluscs. Remains of prey can be seen on the beach during early hours of morning. Wade<sup>12</sup> has reported *Ocypoda albicans* readily consuming *D. denticulatus* from West Indian beaches. The mole crab *E. holthuisi* feeds on suspended matter and smaller planktonic forms employing its unique ciliary mode of feeding in the wash zone. The principal group in the beach fauna, the bivalves, *D. incarnatus* and *D. spiculum* are dominant suspension feeders and their behavioural adaptations and feeding have been described<sup>13</sup>. Some polychaetes, notably onuphids are suspension feeders and these are represented by *Onuphis eremita*. Deposit feeders include *Pisionidens indica*.

**Discussion**

Beach erosion cycle, nature of currents and beach sand movement during the monsoon were found detrimental to the fauna. It was observed in a study at Calangute beach, situated approximately 15 km north of Benaulim, that during the same period, these factors created production instability<sup>4,6</sup>. Examination of beach profiles indicated that apart from the monsoon months (June-September) erosion had been taking place in some post-monsoon months also and that the beach exposure on several occasions was 75 m seawards with rather shallow conditions prevailing (Fig. 1a). Coarser sand encountered during the monsoon had direct bearing on faunal distribution since the changes were detrimental to certain groups, specially crustaceans, polychaetes and gastropods which showed a marked recovery with the return of stable conditions (Fig. 5). The other factors influencing the fauna during

monsoon could be salinity, since it can play an important part in restricting intertidal populations bringing in mortality<sup>14</sup>.

*Population densities and biomass of dominant intertidal fauna* — Table 2 shows comparative densities of dominant species from a few selected beaches. Bivalves *D. incarnatus* and *D. spiculum* were most dominant forms contributing to the beach fauna by their numbers and biomass. Maximum number of *D. incarnatus* (7630/m<sup>2</sup>) was found in February with a biomass of 1340 g/m<sup>2</sup>. *D. spiculum* occurred in patches in November and December with population densities around 6000/m<sup>2</sup> with a biomass of 830 g/m<sup>2</sup>. In 2 beaches studied by Ansell *et al.*<sup>1</sup> the bivalve population was comparatively lower and exhibited a fluctuating trend as in the present study. From the California coast similar fluctuations were encountered in the populations of *D. californica* and *D. gouldii*<sup>15</sup>. Mole crab, *E. holthuisi* occurred in concentration of about 390 individuals/m<sup>2</sup> in January with a biomass of 1020 g/m<sup>2</sup>. Mysid, *Gastrosaccus* sp. occurred in swarms of considerable density (5100/m<sup>2</sup>) during monsoon months. Isopod, *E. peraticis* appeared in densities above 8600/m<sup>2</sup> in July with a biomass of 36 g/m<sup>2</sup>. Variations in biomass and population densities in the study could be due to long shore migration of some species and consequent aggregation which gives rise to erroneous biomass and numbers at any one station, hence extensive comparisons with other tropical beaches were rendered difficult.

*Trophic relationship* — Majority of intertidal community by and large depends on food from sea, part of it occasionally coming from land. Primary production in the water column and surf are important sources of organic matter for the nourishment of sand fauna. Radhakrishna<sup>16</sup> has estimated an annual production of 170 g C/m<sup>2</sup> for shelf waters

TABLE 2 — MAXIMUM DENSITIES OF DOMINANT SPECIES

Species	Density/m <sup>2</sup>	Period of occurrence and location	
MOLLUSCS			
<i>Donax incarnatus</i> *	7630	Feb.	Benaulim, Goa
<i>D. spiculum</i> *	6000	Dec.	Benaulim, Goa
<i>D. incarnatus</i> <sup>8</sup>	18500	April	Calangute, Goa
<i>D. incarnatus</i> <sup>2</sup>	4100	April-May	Shertallai beach, Kerala
<i>D. gouldii</i> <sup>15</sup>	9060		California beach, California, USA
<i>Umbonium vestiarium</i> *	610	Sept.	Benaulim, Goa
<i>Gafrarium pectinatum</i> *	650	Nov.	Benaulim, Goa
CRUSTACEANS			
<i>Emerita holthuisi</i> <sup>2</sup>	2050	April-May	Cochin, Kerala
<i>E. holthuisi</i> *	390	January	Benaulim, Goa
<i>E. analoga</i> <sup>23</sup>	12000-35000		Refugio beach, California
<i>Eurydice</i> sp. <sup>2</sup>	1000	Sept.	Cochin, Kerala
<i>E. peraticis</i> *	8600	July	Benaulim, Goa
<i>E. indicis</i> *	1860	July	Benaulim, Goa
<i>Gastrosaccus</i> sp.*	5100	Sept.	Benaulim, Goa
POLYCHAETES			
<i>Glycera alba</i> <sup>2</sup>	450	May	Shertallai, Kerala
<i>G. alba</i> *	800	Nov.	Benaulim, Goa
<i>Onuphis eremita</i> <sup>2</sup>	1700	Feb.-March	Shertallai, Kerala

\*Present work; other superscript numbers indicate respective references.

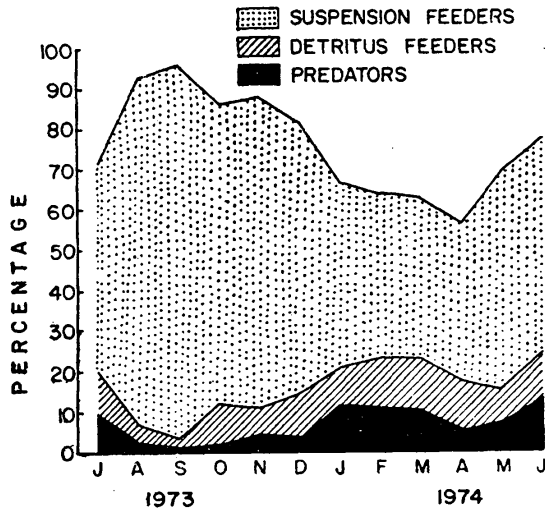


Fig. 6 — Percentage composition of 3 main feeding types (Predators exclude *Ocypodid* crabs)

of India. By some indirect pathways, the water column production reaches subtidal benthos and then on to exposed intertidal fauna by incoming tides. Suspension feeding group in the present study is mainly represented by *Donax* sp. followed by mole crab *E. holthuisi* which also feeds on smaller planktonic forms. Percentage composition of the 3 main feeding types are given in Fig. 6. Detritus feeders are next in abundance specially with a higher percentage occurrence in postmonsoon months. Average value of chl. *a* in the surf is 3.87 mg/m<sup>3</sup> and the particulate organic carbon 1.226 gC/m<sup>3</sup> for the year. According to Riley *et al.*<sup>17</sup> chl. *a* to organic carbon ratio varies from 30-130 (av. 60). Using the average values to calculate the amount of live organic carbon in the form of phytoplankton, the amount of phytoplankton material in water mass approximates 232.2 mgC/m<sup>3</sup> and obviously live phytoplankton material forms a very small part of total organic carbon. It is thus possible that the energy requirement for suspension feeders are met largely by detrital or other components of particulate organic matter and part of the nutrition for deposit feeders are provided by benthic diatoms and dinoflagellates at the sediment surface. Sediment can also be independently considered as an indicator of availability of food<sup>18</sup> as a great deal of organic matter gets accumulated therein. However, the sand organic carbon at Benaulim is very low (755-15 µg/g) and reported value in the nearshore areas is 0.1% (ref. 19).

Mean value of biomass per metre transect at Benaulim beach is 1029.79 g/wet weight, which

when converted amounts to 257.44 g/dry weight. As suggested by Sanders<sup>20</sup> if the production is assumed to be twice the standing crop, this would indicate a production of 514.88 g dry weight/m<sup>2</sup>/transect/year. The assumption of a 10% ecological efficiency<sup>21</sup> would suggest an annual requirement of 2574.4 gC/m<sup>2</sup>/transect/year. Comparing this situation to the beaches studied from the southwest coast of India<sup>1</sup>, total requirement of Carbon/m<sup>2</sup>/transect is very high at Benaulim. Generalizations of this nature can give only a fairly hypothetical estimate of total requirement of the fauna, since biomass of the individual species varies greatly as also life span of the species. More detailed information on life spans of individual species is a prerequisite for coming to any valid assessment.

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