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The Ethologometry of Fishes of the Black Sea Littoral*

A.D. Mochek and S.V. Budaev
Institute of Evolutionary Morphology and Animal Ecology
Russian Academy of Sciences
Moscow

A study of five species of Black Sea coastal fishes was carried out on the basis of an original methodology using underwater video recording and subsequent computer analysis of the data. A detailed analysis was made of the composition and regularities of the interactions of the principal ethological components in relation to the species and a quantitative characterization is given of them. In conjunction with the data on the biotopical distribution and vertical stratification of the fishes, their principal behavioral strategies were determined. The formation of an ethologometric data bank is proposed on the basis of the quantitative criteria that were developed.

Key words: Fishes of Black Sea littoral, ethologometry

Behavioral studies of animals in nature provide valuable information, but they typically encounter difficulties in the complexity of the subject matter. Data objectivity and the validity and repeatability of quantitative criteria for the description of animal behavior in nature remain an important problem. This is especially timely in relation to investigations of fishes. In the ethological sphere, the common use of direct visual methods and the comparisons of synopses of a descriptive character have been used for studies of fish communities of coral reefs (Sale, 1980; Smith, 1978; Hobson, 1965; Gladfelter and Gladfelter, 1978). The ecological-ethological concepts developed in this manner have served as the basis for understanding the community structure of coastal fishes whose most important determinant factor is behavior (Mochek, 1990). This conceptual position, in our opinion, is valid for all stable communities of animals and demands its own development at a new quantitative level.

We have previously proposed a system for quantitative analysis of the everyday behavior of fishes under natural conditions (Mochek, 1987). The classical principle of the comparison of ethograms or of the discrete characterization in time of the constituent elements of the behavioral complex is built into the foundation of this system.

The present study develops the methodological positions that have been worked out, but at the same time envisages a different principle for the accumulation and study of ethological data, based on analysis of underwater video recordings of fish behavior. The analysis of the video data

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in the laboratory makes it possible to analyze rapidly unfolding ethological processes in detail, to identify the structure of behavior, and to accurately measure its principal characteristics. The introduction of a new term, 'ethologometry',[1] is proposed for the designation of the procedure for obtaining data for analysis and describing quantitative ethological criteria of the behavior of fishes.

The aim of the present study is the development of the principles of ethologometry and their implementation based on the example of Black Sea fishes.

Materials and Methods

The collection of the material was carried out at the "Malyy Utrish" (Novorossiysk region) Black Sea biological station of the Institute of Evolutionary Morphology and Animal Ecology, Russian Academy of Sciences, July–August 1991. The processing of the video recordings and the quantitative analysis of the primary data were done in the laboratory of the Institute of Evolutionary Morphology and Animal Ecology in September–November 1991.

The underwater video recordings were made by a diver-researcher. The video recordings were made with a Hitachi (VHS) video camera in a sealed box. The diver's equipment included an AVM-7S aqualung, a wetsuit, mask, and flippers. Observations of two types were used: (1) Individual video monitoring of individuals of various species in order to obtain basic ethologometric data and (2) video recording of control areas to count the fishes in various biotopes.

The study was carried out at depths to 12 m in pebble bed biotopes and Cystoseiraceae groves extending along the shore line. The pebble biotope extends about 10 m from the shore to a depth of 2 m. The substratum consists of pebbles of various sizes, covered by small encrusting organisms. The Cystoseiraceae groves begin beyond the pebble area, and cover the surface of the bottom with a dense carpet over diverse contours of the substratum. The investigations in the Cystoseiraceae biotope were carried out to a depth of 12 m.

About 50 h of underwater work was involved. As a result, 75 video recordings were obtained that were suitable for analysis, including 68 individual monitorings and 7 control sites.

The study was carried out in June–July 1991, with a water temperature along the coast of 16–22 °C. The observations were made only during the day, primarily in calm weather or during mild turbulence.

The video camera followed individual fish for 4–5 min, on the average. In that time, all the visible components of the fish's behavior were recorded: movements and defense, social, and food-procuring reactions. The diver always remained at a distance from the subject being observed to avoid an alarm reaction.

It is evident that the distinction of individual constituents of a behavioral complex is, to a certain degree, an artificial methodological device. The distinction of a multiplicity of ethological

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[1] This translation of the coined term is chosen by analogy. —*Trans.*

Table 1

Fish Composition in Various Biotopes and the Distribution of Fishes in the Water Column

Species of fish	Biotope					
	Pebbles		Cystoseiraceae		Water layer above Cystoseiraceae	
	1	2	1	2	1	2
Reef-fish	0	—	5	51.9	99	—
Eyespot wrasse	8	14.9	84	15.2	0	—
Black Sea blenny	82	0.6	0	—	0	—
Guban goby	6	0.6	0	—	0	—
Annular bream	1	20.0	5	30.4	1	—
Corkwing	3	6.4	5	23.2	0	—
Quail wrasse	0	—	1	6.7	0	—

Note. (1) Composition of fish association, percent; (2) preferred horizon, cm from bottom.

components, based on the structural level of the classification and objective of the investigation, is theoretically possible.

Ten ethological constituents, distinctly recorded on the monitor screen, were distinguished in the study for the purpose of comparison among species (see Table 1). The elements describe all the basic aspects of behavior, the movements of the individuals or their stationary state; the moments of feeding and remaining under cover. The characteristics of social contacts during movements and stops were especially distinguished. The following designations were adopted for these elements of the behavioral complex.

Transition: Alone—SA; in a pair—SP; in school—SS. Use of shelters—H.
Standstill: Alone—STA; in a pair—STP; in school—STS.
Seizure of food: Alone—FA; in a pair—FP; in school—FS.

A detailed protocol of behavior was created for each individual in the process of the analysis, including the sequence and duration of elements distinguished. A Toshiba T3100 computer, working from a specially designed program, was the principal tool of the analysis. The data input into the computer were analyzed, thus obtaining matrices of the frequencies of mutual transitions between the various elements of behavior, and time budgets recorded for each of the species. Analysis of variance as well as the Kruskal-Wallis test were used in statistical analysis of data.

The video recording of the control areas were carried out in two principal biotopes: in the shallow water pebble bed and the Cystoseiraceae groves. A three-dimensional coordinate grid that

limited its boundaries was set up on the area several hours before the video survey. Four vertical rods with contrasting divisions every 20 cm were set up to determine the level of the fish in the water column.

The appearance of fishes of the various species within the limits of the area and the preferred horizon of their movements were recorded.

Results

Distribution of Fishes in Littoral Biotopes

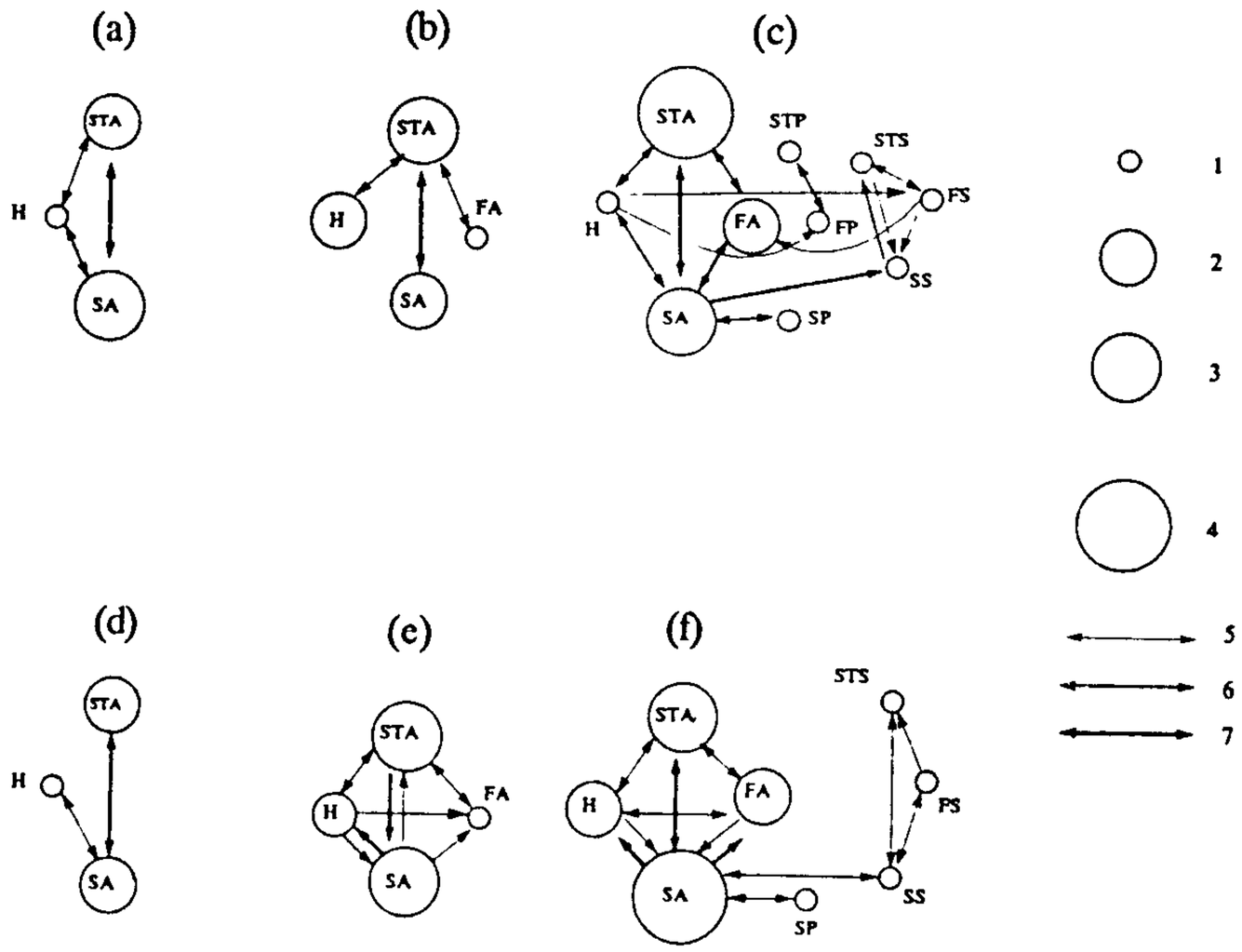
The composition of adult fishes in the two principal biotopes of the littoral zone, the pebble bed and the Cystoseiraceae, differed. These differences were expressed mainly in the relative abundance of the species (Table 1). Thus, in the shallow water pebble bed biotope, the Black Sea blenny, *Blennius sanguinolentis*, made up 82 percent of all the fishes counted; other fishes, the eye-spot wrasse, *Crenilabrus ocellatus*, the Guban goby, *Gobius platyrostris*, the corkwing, *Crenilabrus tinca*, and the annular bream, *Diplodus annularis*, made up, respectively, 8, 6, 3, and 1 percent of the total numbers. By contrast, among the Cystoseiraceae groves, the stationary video camera recorded no Black Sea blennies; eye-spot wrasse made up 84 percent; corkwings, annular breams, and reef-fish, *Chromis chromis*, were 5 percent each of the total, the quail wrasse, *Crenilabrus quinquemaculatus*, which was found only in this biotope, was only 1 percent of the total.

Analysis of the video data makes it possible to assess the preferred position in the water column of the various fish species by biotopes (see Table 1). In the Cystoseiraceae biotope, the water column is exploited mainly by the reef-fish which usually occur at least 0.5 m above the bottom. The annular bream also are encountered primarily in open water, but their movements average 30 cm above the bottom. Below the annular bream, the corkwing movements mainly occur at 20 cm above the substratum. The eye-spot wrasse live in a near-bottom life style, and their movements are usually localized in an area up to 15 cm above the bottom.

The annular bream move at the highest level above the bottom (about 20 cm) in the pebble bed biotope. The movements of the eye-spot wrasse are confined to the 15-centimeter layer, while the corkwings are encountered in the near-bottom layer at about 6 cm. The Guban gobies and the Black Sea blennies inhabit the bottom exclusively, being practically in constant tactile contact with the substratum.

Characteristic of Behavior

The data represented in Table 2 and in the figure reflect the behavior of fishes of various species, allow their ethological comparison, and characterize the biotopical variability of species behavior. Table 2 shows the total time budget of the behavioral reactions characteristic of the various species in the two biotopes, as well as the average isochronous duration of the behavior elements distinguished. The diagram of the mutual transitions of the individual elements (see figure) characterizes the number of manifestations of the individual behavioral acts (diameter of the cir-



Ethological diagrams of endemic Black Sea fishes. (a) Black Sea blenny on pebble bed; (b) Guban gobies on pebble bed; (c) eye-spot wrasses on pebble bed; (d) Black Sea blenny on Cystoseiraceae; (e) corkwing on Cystoseiraceae; (f) eye-spot wrasses on Cystoseiraceae. Frequencies of manifestation of behavioral elements, percent: (1) 20; (2) 30; (3) 40; (4) 50; frequencies of mutual transitions of behavioral elements: (5) 20; (6) 40; (7) 60 percent.

cle) and the frequency of the transitions (thickness of the arrow). Overall, the complex of these indices reflects the species and biotopical characteristics of behavior.

Black Sea blenny. When alone or when grouped in limited areas, few social interactions were observed. Against the background of an almost constant neutral attitude toward conspecific individuals, a few specimens (about 10 percent of the total number according to the data of the stationary recording), on the pebble bed grounds demonstrated marked aggression. A few aggressive individuals were found in constant areas and did not move far from their favored cover.

On the pebble beds, blennies were found to be highly mobile and spent the majority of time (64 percent) moving singly above the bottom. Movements alternated mainly with brief immobility at an open site (18 percent of the time) or with departure into cover. In the process, an individual remained in cover for a long time, 25 percent of the total budget. Stays in cover, 14 s, and solitary movements, 10 s, were the most prolonged elements of the behavior of Black Sea blennies on the pebble bed. Paired and solitary immobility as well as individual foraging lasted on the average about 4 s.

Table 2

Ethologometric Indices of the Investigated Species of the Fishes in Various Biotopes

Element of behavior	Biotope, species of the fishes					
	Cystoseiraceae					
	Black Sea blenny		Eye-spot wrasse		Corkwing	
	1	2	1	2	1	2
SA	11.5	11.1	34.3	8.7	17.9	7.0
SP	0.0	–	7.1	7.4	0.0	–
SS	0.0	–	3.0	4.9	0.1	2.6
H	1.7	6.8	31.6	21.1	72.9	29.1
STA	86.8	138.3	15.3	4.2	6.3	5.2
STP	0.0	–	3.0	5.0	0.0	–
STS	0.0	–	1.7	5.1	0.1	2.6
FA	0.0	–	3.1	3.6	2.7	3.0
FP	0.0	–	0.5	2.2	0.0	–
FS	0.0	–	0.4	2.8	0.0	–
	Pebbles					
	Black Sea blenny		Eye-spot wrasse		Guban goby	
	1	2	1	2	1	2
SA	54.7	10.2	39.7	6.3	3.4	1.0
SP	0.0	–	2.6	6.2	0.0	–
SS	0.8	4.8	1.4	2.5	0.2	3.2
H	5.7	14.1	6.4	5.3	4.9	16.4
STA	18.0	4.5	16.6	3.0	91.0	20.3
STP	0.0	–	1.8	5.7	0.0	–
STS	0.0	–	1.9	5.3	0.3	5.7
FA	0.8	3.9	17.1	5.3	0.2	1.1
FP	0.0	–	9.9	6.1	0.0	–
FS	0.0	–	2.6	15.0	0.0	–

Note. (1) Time budget for the basic ethological components; (2) average duration of individual elements, s.

The behavior of Black Sea blennies was different in the Cystoseiraceae zone. A position of immobility in open areas unequivocally predominated with respect to the total time budget, 86.8 percent. Immobility was replaced by solitary brief movements in open space, taking up 11.5 percent of the time budget. The observed individuals were found in cover only 1.8 percent of the total time. The state of immobility was the most prolonged element of the behavior, about 14.0 s on average; the duration of solitary movements and of residence in shelter did not exceed 11 s on the average.

Guban goby. The behavior of the Guban gobies was observed only on pebble bed grounds, since they were not found among the Cystoseiraceae. As the data obtained suggest, the behavior of the Guban gobies is distinguished by the predominance of passivity. Thus, 91 percent of the entire

time, the fish were observed in complete immobility at an open site, outside of cover. The Guban gobies spend 4 percent of the total time in cover but do so for a considerable length of time, 16 s on average. When they swim out of cover, they immediately freeze without moving, remaining in this condition for 20 s on average. Movements make up only 3 percent of the time budget of these fish; however, brief (1–2 s) movements, replaced by prolonged immobility, are frequently observed, about 30 percent of all transitions. Infrequently (20 percent by frequency), instances of brief (about 1 s) feeding on encrusting organisms on the pebble bed were observed. During the period of our observations, Guban gobies were almost always alone. Only infrequently were brief formations of pairs observed in movement or during immobility.

Corkwing. The video data on the behavior of the corkwings were obtained for the Cystoseiraceae zone. According to the data, corkwings were usually encountered in isolation, in cover for the majority of the time (72 percent) in the Cystoseiraceae groves and crevices of rocks. Corkwings are found in a cover for a considerable length of time (29 s on the average); however, the refuges are not permanent, and the fish often (30 percent of the transitions) change them. Corkwings spend 17 percent of the time changing cover, sometimes (up to 6 percent) stopping for a short (up to 5 s) time. Seizing of food was noted in 30 percent of the transitions; however, the duration of this behavioral element was minimal, and did not exceed 3 s on average.

The substantial polyvariance of the mutual transitions as well as the fairly short duration of the individual behavioral acts attest to the diversity and dynamic character of the ethological stereotype of the corkwing.

Eye-spot wrasse. The behavior of the eye-spot wrasse, among the studied species, is characterized by the greatest complexity. The ethological observations on eye-spot wrasses was collected in Cystoseiraceae and pebble bed biotopes. Their behavior is distinguished by plasticity and varies substantially with respect to biotopes. Thus, when behavior on the pebble bed and among the Cystoseiraceae is compared, significant ethological differences are seen in all types of indices, the time budget, the durations of individual acts and frequency patterns of their mutual transitions.

Individual movement is the dominant ethological element as a fraction, 34 percent, of the total budget on the pebble bed. This form of behavior is replaced in 40 percent of cases by a state of immobility, or in 20 percent by a transition to solitary feeding. Eye-spot wrasses form schools in 10 percent of cases, as well as conspecific pairs. After frequent (30 percent) but brief immobility (about 3 s), the fish may hide in a cover (10 percent), where for the most part movement or foraging continues. The process of feeding in different variants takes up about one-third of the entire time budget on the pebble bed, while this process is more prolonged (15 s) in the school. The isochronous duration of paired and solitary feeding, as of the majority of the other elements does not exceed 4–6 s on the average.

Eye-spot wrasses are less mobile in the Cystoseiraceae biotope (34 percent) than on the pebble bed. A large proportion of the time budget is accounted for by residence in cover (31 percent) or in a slightly mobile state (15 percent). It is instructive that residence in cover (longer than 20 s) is the most prolonged element of the behavior in the Cystoseiraceae. At the same time, immobility *in situ* is brief (up to 5 s). Movements singly or in groups *in toto* take up more than 50 percent of the total time budget with an isochronous duration of 5–10 s. Solitary movement, which

is polyvariantly modified into other forms of solitary or group behavior, predominates by frequency of repetitions in the total behavioral repertoire of the eye-spot wrasses. The set of group relationships is clearly defined and distinct in the ethological diagram of this fish.

The proportion of feeding behavior in the time budget of the eye-spot wrasses in Cystoseiraceae is fairly small, about 3 percent, but, as they are brief (2–3 s), the attempts to seize food is observed frequently in various individuals, up to 30 percent of the total number of instances of behavior change.

When the behavior of eye-spot wrasses and other fishes investigated is compared, the ethological individuality of the representatives of this species is graphically manifested. The ethological diagram of the eye-spot wrasses is fundamentally distinct from that of the other species. When compared with the corkwing, the increased complexity of the behavior is distinctly manifested in the appearance of diverse group elements.

Discussion

The system for recording and analyzing behavioral data proposed in the present paper makes it possible to approach the analysis of behavior of Black Sea fishes in a new way. By contrast with the previous methods (Mochek, 1987), the methodology of the present study makes it possible not only to obtain a notion of budgetary constituents of ethology, but to identify its internal structure as well.

The composition and the proportion of individual ethological components in the time budget, the frequencies and duration of their manifestation, and the tendencies and regular patterns of the mutual transitions were established for each species by analysis of the video data. The comparative ethologometric data, in combination with the data on the biotopical distribution and vertical stratification, make it possible to identify the principal ethological strategies under various conditions.

Thus a highly simplified schema of primarily passive behavior, including a limited number of elements and a clear directionality of their mutual transitions, is characteristic of benthic fishes inhabiting the shallow-water pebble-bed shelf (Guban gobies and Black Sea blennies) in all instances. A practically complete absence of group reactions distinguishes these fishes, and agonistic contacts with conspecific individuals are characteristic of the Guban gobies and Black Sea blennies in a number of instances.

By contrast, active behavior, the manifestation of a wide spectrum of ethological elements, and the polyvariance of the mutual transitions are characteristic for eye-spot wrasses and corkwings, inhabiting the near-bottom horizon in the Cystoseiraceae and on the pebble bed. The behavior of the eye-spot wrasses on the pebble-bed grounds is distinguished by particular complexity. All the elements of active and passive behavior distinguished on the basis of our classification, the formation of groups of various sizes, as well as solitary actions, are characteristic of the fishes in these conditions. The behavior of these fishes in Cystoseiraceae is of a different character, with clear-cut separation of a specific set of school reactions against the background of the nearly total

absence of the complex of paired behavior. It is instructive that, for the Cystoseiraceae biotope, the ethological diagrams of the behavior of the eye-spot wrasse and corkwing with respect to the set of solitary reactions are highly complex, although group behavior is entirely absent in the latter.

The previously established (Mochek, 1987) phenomenon of biotopical variability of behavior characterizes the comparison of the ethologometric data with respect to conspecific individuals (for eye-spot wrasse and the Black Sea blennies) in the various biotopes. The behavior of the fishes in Cystoseiraceae and the pebble-bed shelves differs sharply with respect to all the ethologometric indices examined, budgetary and frequency indices, and duration of particular acts. At the same time, the general diagram of the behavior for the species is always more complex on the pebble bed than on Cystoseiraceae. The latter circumstance, in our view, is determined by the monotonous character of the bottom relief on the pebble bed and the small amount of cover for the fishes.

Thus the results of the present study make it possible to establish the effectiveness of the proposed methods for the purposes of the field ethologometry of fishes. The characteristics of their biotopical distribution, the character of the behavior of the representatives of various species, and the principal features of the ethological specificity of the community have been identified using Black Sea fishes as an example. The further accumulation of ethological materials in accordance with the methodology proposed in the present paper is regarded by the authors as a process of the formation of an ethologometric data bank.

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