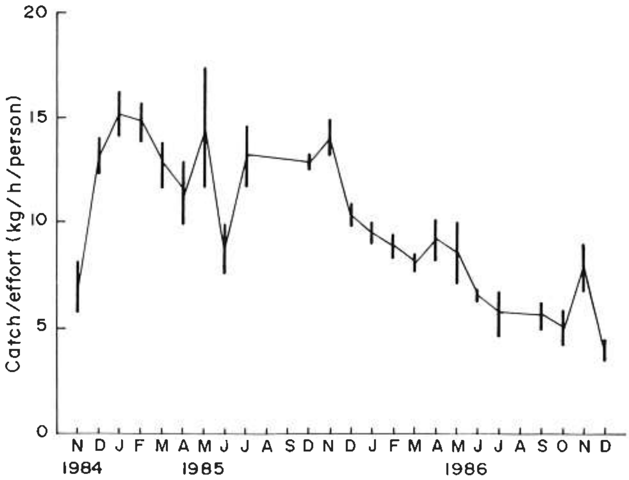

Fig. 5. Time series of catch/effort of yellow clam (± st. dev.) November 1984 and December 1986.

Uruguayan yellow clam fishery, the limited area along which the resource is distributed simplifies the identification and enforcement of low-cost management measures. This makes this fishery an attractive experimental unit to analyze the impact of different management schemes.

Without prejudice to the management issues discussed above, the increase in demand from the domestic and the potential of foreign markets make it necessary to initiate restocking experiments - either by "sowing" or colonization (*sensu* Castilla 1987) - in appropriate areas along the Uruguayan Atlantic coast. Indeed, spontaneous clam restocking activities carried out by fishermen in Uruguayan beaches have been successful.

The present state of the resource suggests that there is presently no need to improve the harvesting technology (Defeo, in press). On the other hand, improving the hygienic and sanitary conditions of post-harvest processing would result in greater value added, which would directly benefit the artisanal fishing community.

Bearing the above considerations in mind, improvements in clam processing and marketing techniques should be promoted both for the present fishery and for newly stocked area within the context of a policy aimed at the development of organized artisanal fishery community centers.

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Computer-Aided Approaches to Identification II. Numerical Taxonomy

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Introduction

This is the second in a series of three Fishbyte articles dealing with computer-based methods to facilitate identification of aquatic organisms. In the preceding article (Froese et al. 1989), IDEXSYS, an IDentification EXpert SYStem for fish larvae of the Northeast Atlantic. IDEXSYS was presented which relies on a text-based approach and which, apart from the fact that it is very comfortable to use and easy to update, functions as would a printed key.

Morphometric measurements in combination with discriminant analysis have been successfully used to identify and separate stocks (Ihssen et al. 1981; Meng and Stocker 1983; Misra and Ni 1983; Misra 1985; Maccrimmon and Claytor 1986; Reddin 1986). This led to the idea of using morphometric measurements and discriminant analysis to build a numerical identification key.

Materials and Methods

The study is based mainly on larvae sampled with R/V Poseidon in the Celtic Sea in April 1986 (Röpke 1988). An interactive image-analysis system was used for quickly and accurately measuring the larvae, of which 781 were included in this study. Two video images of a larva were captured, one in lateral and one in dorsal view and the following parameters were measured: (in dorsal view) standard length, prepectoral length, width between pectorals, width at anus; (in lateral view) preanal length, preorbital length, diameter of eye, depth above eye, depth above pectorals, depth of tail behind anus (Fig. 1). About 50 individuals of each species listed in Table 1, covering the size range from early to late postlarvae (i.e., excluding yolk sac larvae and larvae in the process of metamorphosis) were measured. To approximate multivariate normality and linear relationships, all measurements were transformed to (base 10) logarithms (Bliss 1967; Pimentel 1979). Because what is important are differences in body shape rather than the actual size of body parts, all measurements were corrected for length. This is often done by expressing the measurements as ratios of body length, but according to Pimentel (1979), ratios have unusual distributions and are subject to various errors. Therefore, analysis of covariance was used, as suggested by Ihssen et al. (1981), Misra and Ni (1983) and others, which adjusts each of the morphometric characters to the overall mean standard length according to the formula:

$$AM = OM - (RC * (SL - MSL))$$

where AM is the measurement adjusted for the covariate, OM is the original measurement, RC is the overall regression coefficient between character and standard length, SL is the correlated standard length, and MSL is the overall mean standard length.

Quadratic discriminant analysis is particularly suited to handle different group sizes and different within-group covariances. The method has not yet been used for identification purposes, possibly because of the restriction, emphasized by some authors, that the number of groups should not exceed the number of parameters used. This might be viewed as a serious obstacle, since there are about 120 fish species in the North Sea and adjacent waters, but no more than about ten measurable parameters that can be used for identification of fish larvae. This problem was overcome by a two-step approach, in which similar species were assigned to larger groups. An unknown larva is first classified into one of these groups and then into a species within the group.

The SAS statistics software was used to process the data (Anon. 1985). A cluster analysis (method = WARD) was performed on the arithmetic means of the adjusted measurements for each species to

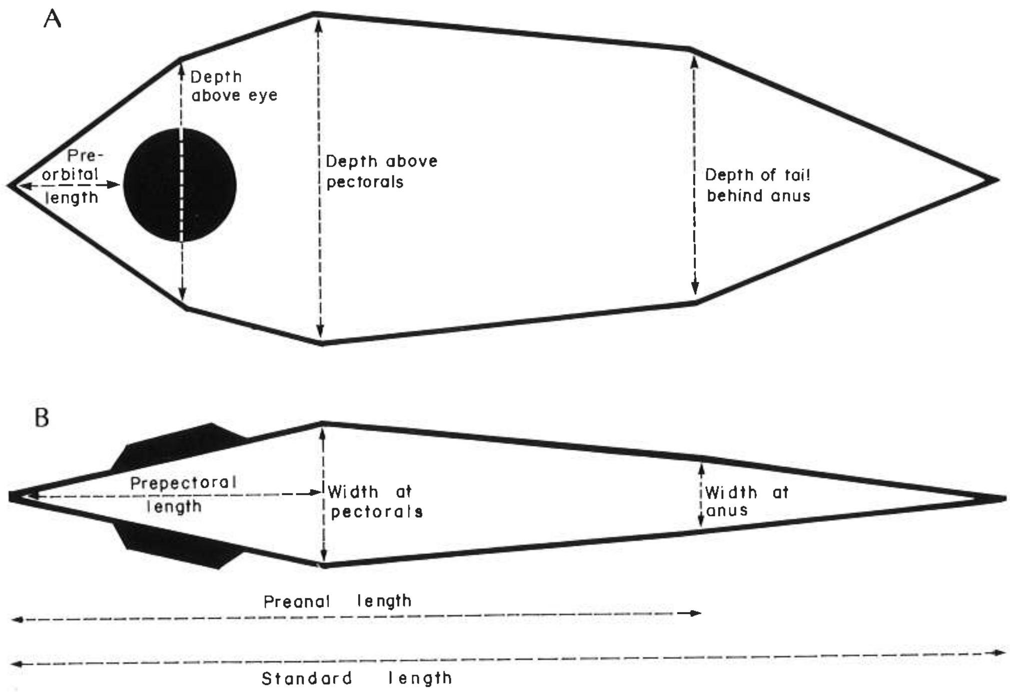

Fig. 1. Measurements performed on the fish larvae (A) lateral and (B) dorsal view.

Table 1. Results of cluster and discriminant analyses (n = number of specimens measured; min SL = minimum standard length; max SL = maximum standard length; Clus. = cluster number; Class. = percentages of observations classified correctly into a) clusters and b) species in the clusters; Prob. = probability of correct identification).

Cluster No.		Species Name	n	min SL mm	max SL mm	Clus. no.	Class. a %	Class. b %	Prob. %
1	1	*Gadiculus argenteus thori*	52	2.48	7.33	1	83	89	74
	2	*Merlangius merlangus*	52	2.35	8.01	1	83	71	59
	3	*Merluccius merluccius*	45	3.08	7.20	1	83	91	76
	4	*Micromesistius potassiou*	30	3.47	9.63	1	83	90	75
	5	*Pollachius pollachius*	51	3.12	11.73	1	83	88	73
	6	*Trisopterus* sp.	51	4.52	11.88	1	83	90	75
2	7	*Lepidorhombus boscii*	42	3.47	8.04	2	96	76	73
	8	*Lepidorhombus whiffiagonis*	44	3.55	12.66	2	96	91	87
	9	*Microchirus variegatus*	32	2.27	7.02	2	96	100	96
	10	Triglidae	37	4.15	15.16	2	96	100	96
3	11	*Benthosema glaciale*	52	4.01	8.07	3	81	100	81
	12	*Callinymus* sp.	84	1.94	9.94	3	81	100	81
	13	*Molva molva*	38	3.16	6.68	3	81	100	81
	14	*Scomber scombrus*	45	2.92	9.16	3	81	100	81
4	15	*Argentina sphyrena*	48	4.87	18.47	4	98	98	96
	16	*Clupea harengus*	50	6.80	19.45	4	98	100	98
5	17	*Glyptocephalus cynoglossus*	28	3.31	12.41	5	96	100	96
		Total	781	1.94	19.45	5	87	93	81

generate clusters of morphometrically similar species. Quadratic discriminant analysis with within-group covariance matrices was used to develop the equations to classify an unknown larva into one of the clusters in a first step, and into one of the species within the cluster in a second step. All 781 measured larvae were used to test the system, i.e., every larva was treated as 'unknown' and classified by the system into a cluster (= group) and a species, resulting in a percentage of correct classification for every cluster and species.

Results

The results of the cluster and discriminant analysis are summarized in Table 1. The result of the cluster analysis is convincing: all gadiforms except for *Molva molva* were grouped into one cluster (#1). Three flatfish and the larvae of the Triglidae family (which resemble the flatfish in lateral view and which are here treated as one "species") were assigned to cluster #2. Cluster #3 contains four roundfish larvae not related to each other. Cluster #4 consists of eel-like larvae with long guts, and cluster #5 contains only one flatfish species (white sole).

The first step of the test put each larva in one of the five clusters. The percentages of correct classifications range from 81% (i.e., 19% belonged to one of the other clusters) for the most heterogeneous cluster (#3) to 98% for the "eel-like" cluster (#2). The percentages of correct classifications in the second step, in which species are identified within each cluster, ranged from 71% for *Merlangius merlangus* to 100% for 7 other species, with an average of 93%. Overall, the probability of correct identification was 81% (the random probability for 17 species would be about 6%).

Discussion

In the light of these results, our two-step discriminant analysis of morphometric measurements seems to be a promising identification tool. The method uses twice the full power of discriminant analysis: while in the first step it might be, e.g., the relation between preanal length and body depth that produces a clear separation between flatfish and eel-like larvae, other parameters might lead in the second step to the segregation of the very similar species within the 'gadiform' cluster. Of course, the user must verify the program's suggestions using traditional methods, e.g., by comparing the larva with a picture and check the most significant characters. The purpose of the system thus would be to guide the user very fast to the most probable species without the need to answer a long list of questions.

Although the method looks promising, it must be emphasized that it requires at least 50 well preserved specimens, covering the whole size range of each species for estimating the discriminant function. Even in the well-explored Northeast Atlantic it was impossible to get enough larvae for more than about 30 species.

This led us to the idea of using descriptions and images from the literature together with a modern database for identification. This will be described in third and last contribution to this series, to be published in the next issue of Fishbyte.

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A Theory of Fishing for a Two-Dimensional World

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Introduction

In 1884, Edwin A. Abbott, a schoolmaster with a passion for theology and literature, published - pseudonymously - a little book titled "Flatland: a romance of many dimensions" in which he explored some of the implications of living in a two-dimensional world.

He described a world in which there is Left and Right, and Back and Forth, but no Up and Down, and dealt with issues such as the climate and houses, the inhabitants (especially the women, who, as opposed to the round males, were pointed and hence, had to be treated with great respect), the problems of color recognition and other issues illustrating the differences between Flatland and a three-dimensional world such as ours.

Mainly, however, he dealt with moral and theological issues - this was the thing to do in the Victorian era. So, the emphasis of "Flatland" was devoted to the conflicts between the local clergy (who were "Administrators of all business, art and science"), and those Flatlanders, philosophers and mystics, who were spreading seditious notions, such as "third dimension", "cube" or "upward".

A.K. Dewdney published in 1984 "The Planiverse: computer contacts with a two-dimensional world", in which the idea of Flatland was carried further