Bolletino di zoologia
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tizo19

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Version of record first published: 14 Sep 2009.

To cite this article: Gilberto Gandolfi , Remigio Rossi , Paolo Tongiorgi , Mara Pesaro & Stefano De Ranieri (1980): Ascent of elvers, Anguilla anguilla (L.), and prospects for their use in aquaculture, Bolletino di zoologia, 47:3-4, 365-380

To link to this article: http://dx.doi.org/10.1080/11250008009438693

Boll. Zool. 47: 365-380 (1980)

Ascent of elvers, *Anguilla anguilla* (L.), and prospects for their use in aquaculture

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ABSTRACT

An overall picture of the European elver's behaviour during coastward migration and entrance into inland waters emerges from a survey of the literature. The factors influencing trophic migration are discussed.

In particular, the data relevant to the Mediterranean area are taken into account. The observations by the authors over the course of one year at the outlet of the River Arno confirm that the behaviour of elvers there is similar to that described for the North Atlantic coast. The ascent of the elvers at the sampling point (located approximately 1100 m upstream from the outlet) is greater in the hours immediately following sunset. A clear-cut influence upon the amount of the ascent is due to tidal movements, and catches are larger after the peaks registered with flood tide. Temperature of the waters appears to have some effect, but no fluctuations in the ascent are attributable to the flow of the river and to the phases of the moon.

The increase in the demand for elvers to replace stocks and for intensive culture is the basis for discussion and analysis of the principal objectives for action aimed at the rational utilization of this natural resource.

THE MIGRATION OF ELVERS

From the numerous studies on the migration of the European eel, *Anguilla anguilla* (L.), the main aspects of the behaviour of this species are well known.

The spawning grounds of the eel are localized in the Sargasso Deep (Western Atlantic) (Schmidt, 1922 and 1923), more exactly at a point not far from the intersection between the Tropic of Cancer and the 60th Meridian West of Greenwich (Bertelsen, 1967). The young larvae *(leptocephali)* begin to appear in April at a depth of 200-300 m, rise to the surface layers, and are transported eastward by the Gulf and the North Atlantic Streams. They reach their maximum development in the third year of life when they are near the European continental shelf. The phase of passive migration ceases and the larvae actively fight the currents when they reach approximately the 1000 m depth line. They remain in this area until metamorphosis is completed (Schmidt, 1928).

The entrance into the Mediterranean occurs in great numbers, depending primarily on the waters flowing from the Atlantic through the Strait of Gibraltar (Schmidt, 1928; Sverdrup *et al.*, 1952). Eel larvae have been reported in the Sicilian Channel, which represents the eastern limit of their distribution. It ought to be noted that the researches carried out by Drilhon & Fine (1971) seem to confirm the existence of spawning grounds in the Mediterranean, which had previously been suggested by some Italian authors (Grassi,

ACKNOWLEDGEMENTS

This research was supported by a grant from the National Research Council (C.N.R.) within the Project for Oceanography and Marine Beds (Sub-Project Biological Resources, Director Prof. G. Bombace). We are grateful to Mr Mario Butturini for his hospitality and technical assistance in the sampling at the Stabilimento Ittiogenico (Marina di Pisa). We are also indebted to Messrs Alberto Ardoni and Vittorio Gaiani, to Misses Paola Giusto and Lalla Zanichelli for their help.

1914; Mazzarelli, 1914; Sanzo, 1928). Nevertheless, Drilhon and Fine's results were strongly criticized by Koehn (1972). Extensive analysis by Rodinò & Comparini (1978a and 1978b) on migrating elvers (still free from selection pressures) demonstrates that the Mediterranean and the Atlantic elvers are genetically uniform and supports Schmidt's assumption that there is a unique breeding area.

To maintain themselves along the edge of the continental shelf the *leptocephali* depend apparently on their auditory and/or lateral line systems, that would be able to detect the resonant effects of surface movements reflected off the ocean floor (Deelder, 1970). The absence of data on the behaviour of elvers in the Mediterranean precludes confirmation of the phenomenon observed in the Atlantic.

Metamorphosis of the *leptocephali* requires some months, during which the young larvae, not feeding at all, decrease in length, a phenomenon that has also been demonstrated experimentally (Grassi & Calandruccio, 1897). The post-metamorphic form, or elver, resumes migration coastward, following, it has been suggested, tidal currents, though this view has been questioned because tidal currents are much less marked in the Mediterranean, and their effects are not detectable at some distance from the coast (Deelder, 1970). Interestingly, the elvers of the American eel, *Anguilla rostrata* (LeSueur), are sensitive in the laboratory to electric fields having the same intensity as those produced by ocean currents (McCleave & Power, 1978).

Researchers unanimously report a progressive decrease in the average length of the individuals that reach the estuarine regions last, in respect to those who arrive first (Johansen, 1905; Grassi, 1919; Strubberg, 1923; Heldt & Heldt, 1930; Menzies, 1936). It is thought that the elvers reaching the coast last metamorphose farther off-shore and that their reduced length is a consequence of the more energy expended on swimming a greater distance (Boëtius, 1976).

In the Atlantic the elvers begin to migrate in September (though some individuals are found in the open sea until November (Schmidt, 1906, and reach the coast in winter, or even later, depending on the distance. Attempts at indicating the periods when the elvers occur at various points along the Atlantic coast have not always been successful. The meteorological changes which signal the start of migration may take place earlier or later from one year to another (Deelder, 1970). According to the computations made by Meyer-Waarden (1965), the speed of the elvers approaching the coast is km/day. But the appearence of elvers along the Dutch coasts in January, in mild winters, would ential a speed still higher. In any case, Deelder (1970) suggested that additional factors, such as coastal currents and tidal movements, are required in order to explain the high speed of migrating elvers. In this phase, according to Creutzberg (1961), the behaviur of the elvers in approaching the coast should be the same as when they enter the estuaries. They should move to the surface waters to be transported toward the coast during flood, and they should sink to the bottom during ebb, which ensures that they are not transported back to the open sea. In the case of juvenile fish, a system of transport based upon tidal movements would require an expenditure of energy per unit distance 90% lower than in the case of active swim (Weihs, 1978).

The last stage in approaching the coast is the " transition period ", i. e. a temporary stage in the estuarine regions prior to entering the inland waters.

The entrance into the estuaries does not seem related to temperature differences (Postma & Verwey, 1950; Deelder, 1952 and 1960). Yet recent research (Westin & Nyman, 1977) indicates that temperature is a basic orientation cue in the migration of silver eels to the sea.

Salinity differences are not important in the approach to the coast (Deelder, 1952 and 1960; Creutzberg, 1961). But temperature and salinity affect the behaviour of the elvers when they stop their migration before the trophic stage. As both Deelder (1952) and Creutzberg (1961) stated, the transition period occurs in water with a high salt content at low temperatures, and in water with a low salt content at higher temperatures. In some cases, due to a sudden cold spell, the elvers, after entering the estuaries, return to the open sea.

Tidal currents play a central role. In the first place, they trigger vertical displacements of the elvers, which rise into the surface waters during flood and descend during ebb tide (Creutzberg, 1958 and 1961).

Darkness also plays an important role in the migration to the estuarine regions and determines an increase in swimming activity (Deelder, 1952).

The influence of the phases of the moon is not clear. According to Gollub (quoted by Gibson, 1978), the catch of elvers should be greatest in the last quarter and in the new moon. On the contrary, Meyer & Kuhl (1953) did not find a clear-cut correlation between the phases of the moon and the amount of the catches. As Deelder (1960) pointed out, apparent effects should be attributed, most probably, to the effect of the phases upon the tides.

In general, the elvers respond to freshwater currents by swimming against the currents, though it has been shown that this innate behaviour requires a period of maturation. In fact, the elvers that have been caught in the open sea immediately after metamorphosis do not respond to freshwater currents, nor do they exhibit any avoidance behaviour; while the response of the elvers taken later increases with increasing stay in salt waters. However, the elvers taken in inland waters when put into waters more or less salty will respond immediately to a freshwater current by swimming against it (Deelder, 1958). One possible explanation of this behaviour is that the elvers gradually acquire new physiological functions which enable them to adapt to radical environmental changes. These changes presumably occur in the transition period and would explain why the elvers stop in the estuarine regions before the last stage of trophic migration.

Thus, the ability to discriminate among tidal movements seems to be the principal factor regulating the behaviour of entrance into the estuaries. According to Creutzberg (1959 and 1961), the preference for fresh waters as compared to marine waters, which has been previously assumed on the basis of experimental data (Fontaine & Callamand, 1941; van Heusden, 1943, quoted by Deelder, 1970), would not depend upon salinity differences, but upon the specific odours of inland waters. When one eliminates these factors by filtering the waters with charcoal, preference responses disappear.

It is well known that the entrance into the estuarine regions is followed by increasing pigmentation. This process, as Strubberg (1913) pointed out, is affected more by temperature changes than by other factors, such as salinity or light. Pigmentation marks the end of the elver stage.

THE MEDITERRANEAN ELVERS

Most of the data on which our previous considerations are based came from research in the coastal section of the Northern Atlantic. The data on the Mediterranean region cannot always be used for comparison. Lack of continuity in space and time make it difficult to build an overall picture of the ascent of the elvers in the Mediterranean.

The salient aspects of this phenomenon in the Mediterranean were summarized by D'Ancona (1940) in a preliminary introduction to data collected in the Adriatic Sea. First, he examined the amount of the

Table I — *Samples taken at Bocca d'Arno: summary data.*

No. and date of samples	No. of samples taken over 24 hours	Total number of elvers	Average number of catches per sample
1 - 1978, Oct. 26	13	—	—
2 - Nov. 29	7	—	—
3 - Dec. 13-14	19	104	5.47
4 - Dec. 28-29	19	138	7.26
5 - 1979, Jan. 11-12	23	21	0.91
6 - Jan. 24-25	24	142	5.92
7 - Feb. 14-15	24	456	19.00
8 - Feb. 26-27	24	35	1.46
9 - Mar. 14-15	24	533	22.21
10 - Mar. 28-29	24	282	11.75
11 - Apr. 10-11	23	24	1.04
12 - May 10-11	21	459	21.86
13 - Jun. 14-15	7	41	5.86
14 - Jul. 12-13	7	37	5.29
15 - Aug. 7	6	2	0.33
Total	265	2274	8.58

ascent which had been thought to be more abundant along the southern coast of France, in some parts of the Tyrrhenian Sea, and in the Nile, but less abundant in others. It should be noted, however, that the problem has never been investigated for wide sections of the Mediterranean coast. According to D'Ancona (1940), on the basis of previous data (Gandolfi-Hornyold, 1920 and 1934; Athanassopoulos, 1928 and 1936; Strubberg, 1923; Hovasse, 1927; Chiappi, 1932), the ascent does not present any decreasing trend from West to East, as observed in the North Sea. Nevertheless, it may be argued that the area where metamorphosis occurs, and from where the elvers radiate, is the Western Mediterranean. This would explain why the elvers appear almost simultaneously along the coasts of Spain, France, and Western Italy. The only data that do not agree with this assumption concern the Nile Delta, where the elvers are observed in two different waves: the first very early, in October-December; the second in March-July (Paget, 1923; Strubberg, 1923; Lübbert, 1930). This phenomenon may be explained by the transportation of the elvers toward the Eastern Mediterranean in two different currents (Deelder, 1970).

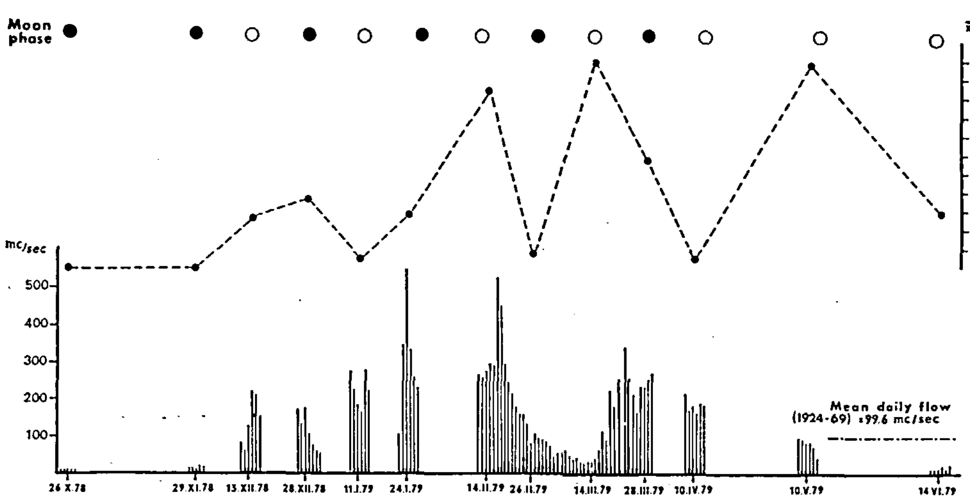

Fig. 1. — Variations of average number of elvers per sample ($\bar{x}_n$) in relation to the flows of River Arno (mc/sec) and to the phases of the moon.

As to the Italian coasts, D'Ancona reported a delay in the ascent in the upper Adriatic Sea (February-March) as compared to the Tyrrhenian Sea (October-November). Finally, he confirmed that the length of Mediterranean elvers is less than that of Atlantic elvers, and attributed this difference to the time spent in warmer waters, entailing a more pronounced decrease during metamorphosis (Strubberg, 1923; Gandolfi-Hornyold, 1924).

The reports by Chiappi (1931 and 1932) seem rather unusual. He stated that the ascent is less abundant in odd years, reaching a peak in January, and more abundant in even years, with a peak in December. He noted morphological and histological differences between elvers ascending in even years and those ascending in odd years. Finally, it is rather difficult to accept the extrapolation of this author on the different average dimensions of the samples taken in different, but close, points along the coast of Latium and Tuscany.

The only research based on continued sampling was done recently by Finiger (1976) in a brackish-water lagoon in the South of France. She showed that wind is a primary factor affecting the ascent of the elvers. The strong winds blowing from the North cause the outflow of waters from the channel which connects the lagoon to the sea.

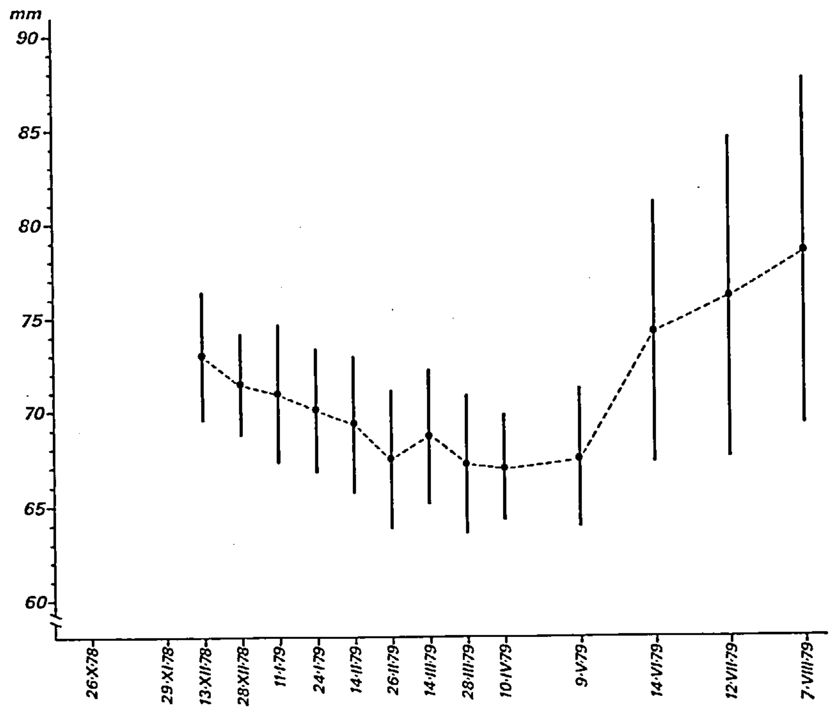

Fig. 2. — Variations in average length (± standard deviation) of elvers caught at Bocca d'Arno.

THE ASCENT OF THE ELVERS AT THE OUTLET OF THE ARNO

Owing to a lack of systematic research in assessing the various factors affecting the ascent of elvers in the Mediterranean, we started to collect samples at regular

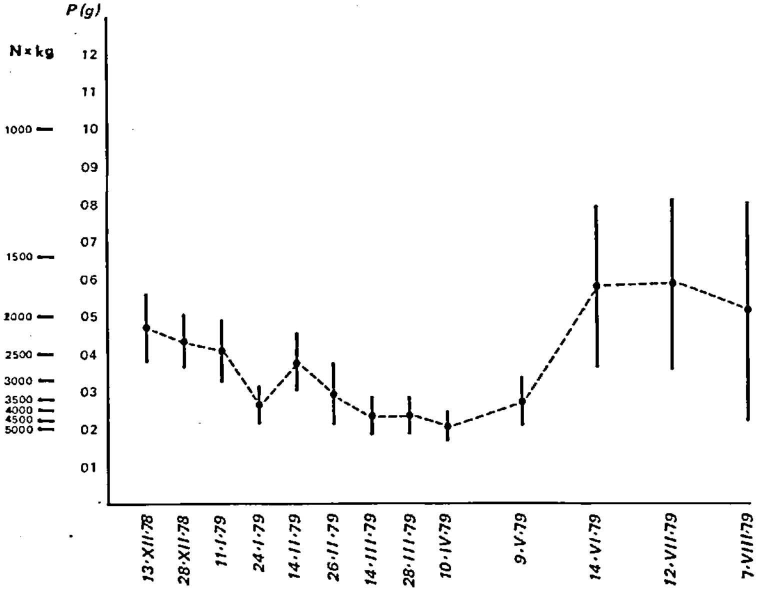

Fig. 3. — Variations in average weight (P ± standard deviation) and number of individuals per kilogram (No. × kg) of elvers caught at Bocca d'Arno.

intervals at the outlet of the River Arno (Bocca d'Arno, near Pisa). Samples were taken every hour, over a period of 24 hours, every fortnight (October-April) or every month (May-August) at the outlet

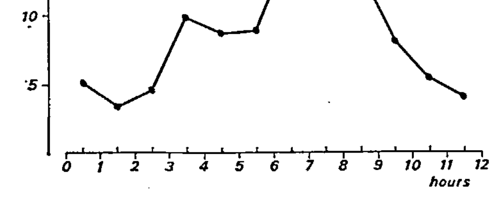

Fig. 4. — Variations in average number value of elvers per sample (X/N_p) over one complete tidal cycle.

of the Canale del Lamone, a channel whose waters flow into the River Arno approximately 1100 m upstream from the sea. Sampling techniques have been rigorously standardized to obtain comparable results. Those from our first year's research have been published only in part (Gandolfi *et al.*, 1979a and 1979b) yielding a clear enough picture of the ascent of the elvers in this river.

In 1978-1979, the ascent began in December, reaching a peak in February-March, and ceased almost completely after July. Wide fluctuations were observed also in the period of maximum ascent (Table I). The delay observed in the starting of the ascent, in contrast with the data reported in the literature (Chiappi, 1931 and 1932; D'Ancona, 1940), is probably due to the state of drought of the river during that autumn. Nevertheless, it must be noted that the delay does not depend directly on the low flow of the stream. Rather, it can be attributed to the extreme organic pollution of the bed, a condition which lasts until the first autumnal floods. In fact, the fluctuations do not seem to have a direct effect on the amount of the ascent, since our data show rather large numbers of elvers in both drought and full-flood (Fig. 1).

The average length of the elvers (Fig. 2), as measured on anaesthetized specimens, and the average weight (Fig. 3) as measured on those fixed in a 4% formol solution, vary during the year. A decrease is observed until the first stages of pigmentation prevail in the samples (stages 1-8, according to Grassi, 1914 and stages A-C, according to Boëtius, 1976). In December-April the decrease amounts in length approximately to 6 mm, and in weight to more than 200 mg. Afterwards, an increase in length and weight is observed, and the coloured elvers prevail. An increasing proportion of individuals which have adapted to freshwater environments and are in the full trophic stage is contained in the samples collected in this period (Fig. 6).

Variations in the amount of the ascent cannot be directly related to different phase of the moon (Fig. 1). Due to lack of data no conclusions can be drawn about the effects of winds. However, it must be noted that the ascent is small with prevailing northern winds, which clearly disagrees with the data published by Finiger (1976). One explanation for this is that the orientation of the outlet of the River Arno is different from that of the environment studied by that author; or it may be that the temperature of the waters it lower with northern winds. High numbers were registered with both south-east and south-west winds, but no significant differences were found.

The temperature of the waters appears to have a marked effect on the ascent of elvers, which decreases or disappears completely under 9 °C and above 23 °C (Fig. 5). The lower limit is reasonably reliable and agrees with previous observations (Schmeidler, 1957 and 1963; Creutzberg, 1961). However, the upper limit is less reliable. In fact, few of the samples were collected at temperatures higher than 17 °C, and all of them in summer when the ascent is greatly reduced.

Tides have a clear-cut effect. Wilcoxon's test (Siegel, 1956) applied to the average number of catches in two different intervals of the tidal cycle confirmed that the ascent is significantly different (Table II). Time intervals were measured between two successive points of inflection along the graphs registered by the tide gauge at Bocca d'Arno, near the sampling station. On the contrary, comparison between periods of flood and periods of ebb does not reveal any significant difference (Table III). Moreover, Friedman's two-way analysis of variance (Siegel, 1956) applied to four different sub-inter-

Table II — *Comparison between the average numbers of elvers in the samples collected in two different intervals during the tidal cycle:* max = *time interval between the inflection points before and after the maximum water level;* min = *time interval between the inflection points before and after the minimum water level;* T = *sum of less frequent ranks;* p *is tested by the Wilcoxon matched-pairs signed-ranks test.*

Sample no.	max	min	Difference	Rank
3	4.91	6.25	−1.34	−5
4	8.82	3.73	5.09	7
5	1.09	0.75	0.34	3
6	8.42	3.42	5.00	6
7	25.58	12.42	13.16	11
8	1.92	1.00	0.92	4
9	31.92	12.50	19.42	12
10	15.50	8.00	7.50	9
11	1.09	1.00	0.09	1
12	38.45	3.60	34.85	13
13	8.20	0.00	8.20	10
14	7.20	0.50	6.70	8
15	0.33	0.00	0.33	2
Total average	12.80	5.06	7.74	$T = -5$, $p < 0.01$

vals in one complete tidal cycle shows significant differences. The highest numbers were found in the phase of ebb between the minimum level and the ensuing point of inflection (Table IV and Fig. 4). This result clearly disagrees with the observations made by Creutzberg (1961). However, two comments need to be made here. First, since our sampling station was 1100 m from the sea, the elvers starting to ascend with flood were delayed in reaching the station. Secondly, since the station was at the outlet of a tributary channel, the increasing numbers caught at the start of ebb probably depended on the search by the elvers for a shelter along the sides of the river, not to be carried back to the sea.

The mean percentage values of the ascent for each hourly sample has been computed in order to compare the samples independently from the number of catches in each daily sample. Comparison between the values of this index has revealed a peak between 7 and 11 p.m. (Fig. 7a). The peak becomes more marked when time is measured from sunset, rather than midnight, given that the sunset time varies with the season (Fig. 7b).

Thus, the highest numbers in the ascent occurred around sunset, due to the simultaneous action of the two factors af-

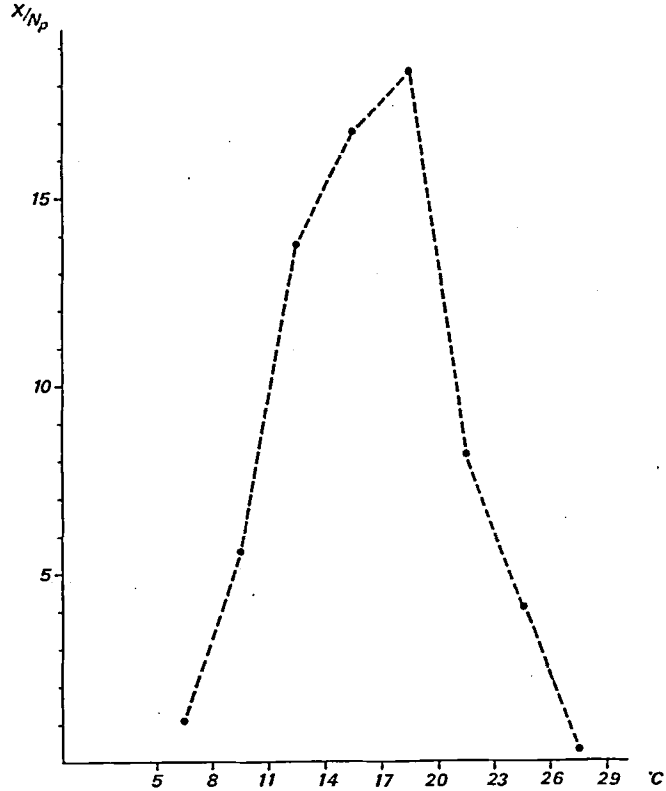

Fig. 5. — Average number of elvers per sample (X/N_p) at different intervals of temperature (°C).

Table III — *Comparison between the average numbers of elvers in the samples collected during ebb and flood tide:* T = *sum of less frequent ranks;* p *is tested by the Wilcoxon matched-pairs signed ranks test.*

Sample no.	Ebb	Flood	Difference	Rank
3	3.60	7.56	− 3.96	− 9
4	5.00	7.33	− 2.33	− 7
5	1.27	0.58	0.69	3
6	8.75	3.08	5.67	10
7	22.92	15.08	7.84	11
8	2.58	0.33	2.25	6
9	15.92	28.50	−12.58	−12
10	11.67	11.83	− 0.16	− 2
11	1.67	0.36	1.31	4
12	41.45	0.30	41.45	13
13	3.50	6.80	− 3.30	− 8
14	6.50	4.80	1.70	5
15	0.33	0.25	0.08	1
Total average	11.06	7.30	4.76	$T=-38$, $p>0.05$

fecting the ascent into internal waters. Confirming Tesch's (1965) observations, Table V shows that flood tides in early morning at times may facilitate the ascent during subsequent full light hours.

PROSPECTS FOR THE UTILIZATION OF ELVERS

In coming years there will be a growing demand for elvers and young eels for two reasons:

(i) the need to replace the stocks in the basins where ascent cannot take place for various causes;

(ii) the need for elvers and young eels for both extensive and intensive aquaculture.

In the first case, the lack of elvers upstream from dams or other structures which regulate the flow of waters can be overcome by installing fish ladders, commonly used in Northern Europe. However, this is not always possible.

The use of artificial breeding methods appears somewhat premature. Adult eels begin to migrate at a time when their gonads are not fully developed, and attain maturity at sea. There have been many attempts to induce sexual maturation in the case of the European eel, with only partial success (Boucher *et al.*, 1934; Schreiber, 1935a and 1935b; Fontaine, 1936; Tuzet & Fontaine, 1937; Landgrebe, 1941; Van Oordt & Bretschnei-

Table IV — *Comparison between the average numbers of elvers in the samples collected in four different intervals of the tidal cycle (numbers in parenthesis indicate the ranks used in computing* χ^2 *by the Friedman two-way analysis of variance):* I = *interval between the inflection of flood tide and maximum water level;* II = *interval between the maximum water level and the inflection of ebb tide;* III = *interval between the inflection of ebb tide and the minimum water level;* IV = *interval between the minimum water level and the inflection of flood tide.*

Sample no.	I	II	III	IV
3	6.80 (3.0)	3.33 (1.0)	4.67 (2.0)	7.20 (4.0)
4	13.00 (4.0)	10.67 (3.0)	3.60 (1.0)	3.83 (2.0)
5	0.50 (1.0)	1.80 (4.0)	0.83 (3.0)	0.67 (2.0)
6	3.00 (1.0)	13.83 (4.0)	3.67 (3.0)	3.17 (2.0)
7	19.00 (3.0)	32.17 (4.0)	13.67 (2.0)	11.17 (1.0)
8	0.67 (2.0)	3.17 (4.0)	2.00 (3.0)	0.00 (1.0)
9	45.83 (4.0)	18.00 (3.0)	13.83 (2.0)	11.17 (1.0)
10	16.83 (4.0)	14.17 (3.0)	9.17 (2.0)	6.83 (1.0)
11	0.20 (1.0)	1.83 (4.0)	1.50 (3.0)	0.50 (2.0)
12	0.17 (1.0)	84.40 (4.0)	5.67 (3.0)	0.50 (2.0)
13	11.33 (4.0)	3.50 (3.0)	0.00 (1.5)	0.00 (1.5)
14	7.67 (4.0)	6.50 (3.0)	0.00 (1.0)	0.50 (2.0)
15	0.33 (3.5)	0.33 (3.5)	0.00 (1.5)	0.00 (1.5)
Total average	10.21	16.18	5.66	4.24
Sum of ranks	(35.5)	(43.5)	(28.0)	(23.0)

$\chi^2 = 11.1$, $p<0.02$

der, 1942; Bernardi, 1948; Bruun *et al.*, 1949; Gineste, 1955; Møller-Christensen *et al.*, 1958; Olivereau, 1961; Boëtius *et al.*, 1962; Fontaine *et al.*, 1964; Boëtius & Boëtius, 1967; Lumare & Villani, 1973; Meske, 1973; Villani & Lumare, 1975). For the most recent experiments, the monograph by FAO (1976) is recommended. Artificial fecundation has been successful in the case of the Japanese eel, *Anguilla japonica* Schlegel, but the larvae survived only a few days (Yamamoto & Yamauchi, 1974). It may be possible in the future to obtain artificial reproduction for the European eel, but culture of the larvae will pose a difficult problem because of their peculiar biological cycle. Consequently, it will be necessary to obtain individuals from natural stocks.

In our country, the availability of elvers in the near future will depend entirely upon correct usage and rational conservation of the catch sites. In this regard, attention must be paid to the negative experience of Japan, where the increase in the demand for the elvers, *A. japonica*, for intensive culture was followed by a strong decrease in their availability, a decrease aggravated by growing water pollution along the coasts and in the estuaries (Querellou, 1974). In 1971 Japan had to import from at least ten different countries (including Italy) more than 300 tons of elvers and young eels belonging to four species (Matsui, 1972, quoted by Querellou, 1974).

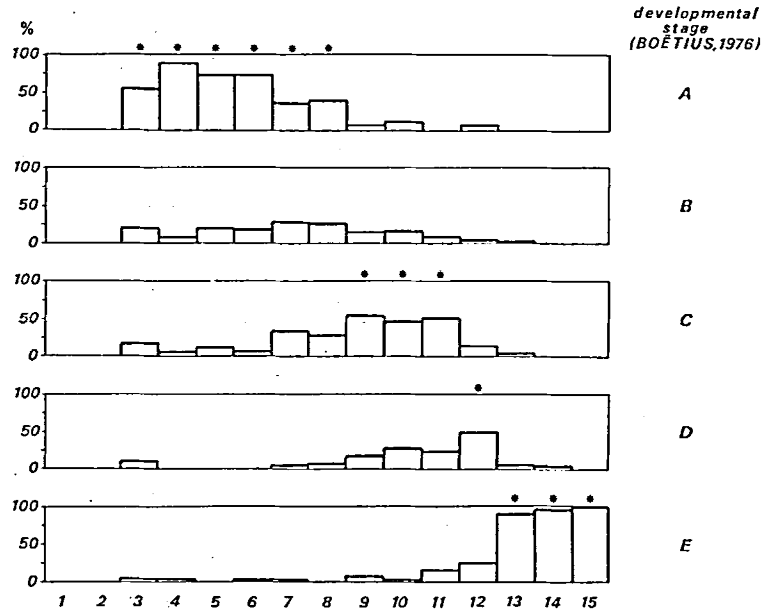

Fig. 6. — Percent frequencies of the five developmental stages in the samples; asterisks indicate the most frequent stage in each sample cycle.

Correct usage of the elvers migrating into our waters would require a complete understanding of a situation that is still largely unknown. The main objectives for action should be as follows:

1. *Estimate of the ascent.* Comparative research along the Adriatic and Tyrrhenian coasts has shown that the ascent is

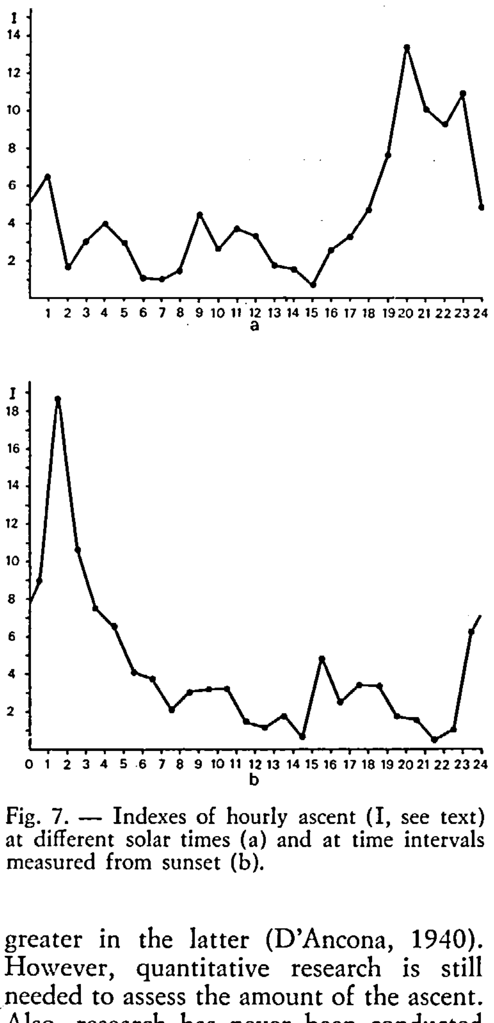

Fig. 7. — Indexes of hourly ascent (I, see text) at different solar times (a) and at time intervals measured from sunset (b).

greater in the latter (D'Ancona, 1940). However, quantitative research is still needed to assess the amount of the ascent. Also, research has never been conducted in many areas where ascent occurs (South Tyrrhenian, Sicilian, Sardinian and Ionian coasts).

2. *Estimate of the potential for catch.* Catch of the elvers is advisable in those areas where the ascent occurs in great numbers, provided that the natural populations are not adversely affected. But the amount and the periods of catch must be assessed on the basis of *ad hoc* research. Some indications may be obtained from our previous data. For example, the ascent is large in streams with limited biological capacity, particularly along the Maremma coast. In these environments, the catch of the elvers is not liable to affect natural populations. A large, or even massive, catch can be made in the environments where pollution is particularly strong, since the fish would not survive just upstream of the outlet. Finally, the catch is especially favourable at those points where water scooping machines are used for draining purposes, since the elvers will gather in large numbers being unable to continue their migration into areas where they can complete the trophic phase.

3. *Planning and control of catch.* Given the present circumstances, it is urgent to evaluate the opportunity of granting fishing permits for market consumption of elvers. As to catch permits aimed at culture or replacement of stocks, the action recommended is the same as that suggested for mullets and other fry of brackish-water species (Gandolfi *et al.*, 1978). In Italy the transfer of certain administrative units from the State to the Regions provides an opportunity to local administration to install catch and stocking plants at relatively low cost. Such an opportunity exists for example in the Stabilimento Ittiogenico at Marina di Pisa, where our research is done.

4. *Research on the elver's natural feeding habits.* The studies made on the outlet of the Arno show that elvers change their characteristics as the ascent progresses. In particular, there is a gradual increase in the number of elvers in the more advanced stages of pigmentation. Furthermore, the frequency of individuals with food residues in the digestive tract increases with increasing pigmentation (Table VI). In view of obtaining a better culture, it is important to assess in this case the feasibility of using elvers at the initial phase of ascent who have not yet begun to feed, or elvers who are feeding themselves being toward the end of the ascent. Knowledge, at present inadequate,

Table V — *Number of elvers caught in each replicated sample (— time of sunset; ❊ maximum water level).*

Sample no. / Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1			10	6	0	0	3	7	40	14	0	5	5	7	
2			2	2	0	0	7	0	19	22	0	1			
3			9	4	1	2	3	0	18	25	0	0			
4			4	12	0	0	4	0	37	8	3				
5			7	5	0	0	0	3	25	6	1	0			
						❊									
6			6	3	0	0	2	0	3	6	0	0			
7			0	1	0	11	0	0	0	3	0	0			
					❊			❊			❊	❊			
8			7			5	0	0	0	4	0	0			
			❊	❊						❊					
9			0		6	9	2	0	0	2	0				
							❊		❊						
10	0		1		3	5	25	0	2	2	0	2			
11	0		3		2	7	83	0	3	3	0	3			
	❊														
12	0		2		3	2	69	0	4	1	0	2			
13	0			0	0	10	40	0	0	1	0	2			
14	0				0	1	6	23	0	4	0	0	1		
15	0			1	0	6	6	0	2	1	0	0			
16	0			1	2	2	13	0	1	0	0				
		—	—	—											
17	0	0	14	0	3	8	11	0	0	1		1			
	—	❊			—	—❊	—								
18	0	0	17	25	0	32	37	0	1	0	0	0	0		0
								—	—	—	—				
19	0	0	4	25	0	17	30	1	90	13	0	0	0	0	1
					❊			❊			❊	—❊			—
20	0	0		11	0	18	64	11	143	75	4	154		1	0
			❊	❊						❊			—	—	❊
21	0	0	6	7	0	0	18	6	42	38	6	193	6	6	0
							❊		❊						
22	0	0	9	11	0	1	4	2	24	16	1	73	22	11	0
23		0	1	14	0	0	7	5	34	24	6	18	6	6	1
	❊												❊	❊	
24			2	10	0	1	5	0	41	17	3	4	2	6	
Totals	0	0	104	138	21	142	456	35	533	282	24	459	41	37	2

of the feeding habits of elvers and young eels in natural environments is essential for aquaculture.

5. *Conditions of culture.* Further action is needed, as well, concerning eel culture, a subject difficult to investigate owing to the lack of information in the literature. It is well known that there has long been an interest in the culture of elvers in the brackish lagoons of Veneto (Valli), where ascent occurs is small numbers and natural populations have had to be increased through artificial culture. For this purpose, classical experiments

Table VI — *Absolute* (n) *and percent* (%) *frequencies of elvers with food residues in their digestive tract.*

Stage of pigmentation (according to Boëtius, 1976)	No. of examined elvers	Elvers with food in digestive tract n	%
A	578	58	10.0
B	339	41	12.1
C	731	230	31.5
D	445	214	48.1
E	220	148	67.3
Total	2313	691	29.9

were carried out at Valle Nuova by Bellini (1907). He attained good results by sowing elvers and supplementing their diet with offal from butchers' shops and with intensive cultures of Gammaridae. Sowing of elvers is a controversial subject in the case of Valli, where commercial fishery is practised. The use of later developed stages has been advised (Korringa, 1976). For example, Rossi & Papas (1979) have estimated (for the same Valle Nuova) that 2-12% of the elvers survive, as opposed to 30-60% of the young pigmented eels. Present practice is exactly the reverse, and elvers, rather than young eels, are being used, though as a result of the difficulty in finding young eels. However, as we have established for some water courses along the coasts of Tuscany, it is evident that the difficulty of finding young eels on the market does not necessarily reflect their real scarceness in natural environments.

In Italy, where intensive breeding is still in the developmental stage, the demand for elvers is small. But it can be foreseen that the demand will increase substantially in the next few years. At present, elvers are supplied mainly from the Mediterranean (largely from France), but problems from parasitic infestation by *Mixidium giardii* had necessitated that elvers be transported from the Atlantic. The situation in Italy is anomalous: our country exports elvers and young eels to Japan, while importing elvers from other European countries. We are not sure whether this paradox stems from economic factors or from disorganization.

CONCLUSION

It was not our aim to reveal new information on the eel, a species well known from a biological point of view. Rather, our main concern in collecting information and in planning our research was to obtain results of use in aquaculture. Our ultimate goal would be to develop a rational policy combining commercial fishing and protection of this invaluable fish.

The lack of data necessary for the proper utilization of eel stocks becomes evident in trying to integrate biological concepts and practical applications. This fact emerges clearly from the FAO Symposium at Helsinki (1976), and our research has been inspired by its recommendations.

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