STUDIES ON THE FAUNA OF CURAÇÃO AND OTHER CARIBBEAN ISLANDS: No. 120

ECOLOGY AND MORPHOLOGICAL CHARACTERS OF DIFFERENT POPULATIONS OF POECILIA SPHENOPS VANDEPOLLI

(Cyprinidontidae)

by

CONSTANCE A. FELTKAMP & INGVAR KRISTENSEN

(Caribbean Marine Biological Institute, Curação)

Poecilia sphenops vandepolli is one of the most common fishes along the coasts of the Netherlands Antilles, opposite the Venezuelan coast. It is found in the sea, in fresh water and in supersaline water.

The first description of this fish was given by VAN LIDTH DE JEUDE (1887) who named it *Poecilia vandepolli*. The type specimens had been collected in a Curaçao fresh water rivulet. In the same paper, the author described some specimens from Aruba as a subspecies (*Poecilia vandepolli arubensis*) because of small differences in the ratio of total length and depth of the peduncle. Metzelaar (1919), however, suggested that these differences might be due to the variability of the species and that not enough specimens were examined.

REGAN (1907) found vandepolli to be synonymous with sphenops. MEEK (1909) mentions the Curaçao fishes as Girardinus vandepolli. HUBBS (1926) came to the conclusion that the Antillean species is almost identical with the mainland species Mollienisia sphenops when he writes (p. 78): "M. sphenops vandepolli is very similar to M. s. cuneata, but usually differs in the development of a dark blotch approximately opposite the middle of the pectoral fin. No such spot is indicated in our specimens of cuneata, but is developed in some

Present address of second author: Netherlands Institute for Sea Research, Texel, The Netherlands.

examples of sphenops from Panama and Costa Rica" (cuneata is the subspecies from Colombia and Venezuela). Schultz (1949) apparently found no differences between the Antillean and Venezuelan populations as he mentions the specimens from the Venezuelan coast as Mollienisia sphenops vandepolli.

Sanders (1936) also followed Hubb's nomenclature when mentioning the species from the Netherlands Antilles. De Beaufort (1940), however, uses Mollienesia vandepolli when recording the species from Bonaire, Curação and Aruba. Bailey & Miller (1950) showed that the orthography of this genus, indeed, should be Mollienesia, and not Mollienisia as used by most authors. Rosen & Bailey (1963) lumped Mollienesia and several related genera together into one genus Poecilia. Concerning the Antillean population vandepolli they are in doubt whether this group should be considered to be a valid species or just a subspecies. Our data are insufficient to clear up the relationship between the Antillean vandepolli-group and the continental sphenops populations, and our decision in this respect to follow Hubbs' nomenclature is therefore an arbitrary one.

The Antillean "molly" is variable in many respects. Males belonging to the same population show large differences in colour. In some the colour is grayish brown as it is in the females. In other males the flank may be yellow with a bluish hue, and they may have an orange throat and an orange red dorsal fin with a black edge. On the trunc and tail some 10 to 12 grey, vertical bands are often present. Behind the base of the pectoral fin a black spot as large as the eye is usually, but not always, present. The colour of the female is grayish brown. Some females may show a greenish or bluish hue on the back.

Along the Golfo de Venezuela and in Trinidad and Barbados part of the specimens have irregular black spots on the body (personal observation, I.K.). These spots may have a diameter of some mm only, but they can also form patches so that the appearance of the fish is greyish or even black, especially in the males. In the Netherlands Antilles, however, we never found any spotted animals.

In some populations the maximum size of the males is 5.3 cm, but in other populations the males do not exceed 2.6 cm. The females show maximum lengths of 9.6 cm in one and 3.2 cm in another population. According to REGAN (1913, p. 1013) who examined specimens from the mainland and from the Leeward Islands, *Poecilia sphenops* may even reach a larger size: "numerous examples to 120 mm in total length from all parts of the range of the species".

The males mature at a size varying from 2.1 cm to 3.2 cm (total length); in females the variation is from 2.3 to 5.5 cm. The molly is ovoviviparous; small females of 3 cm produce about 10 young a time, and big ones of 9 cm have litters of one hundred or even more.

In general the females outnumber the males, the ratio being often 2:1, but sometimes the difference is less. The same was found in the mainland population: for Panamá Meek & Hildebrand (1916, p. 328) mention a sex ratio of 3.7 or even more females to every male.

The mainland *Poecilia sphenops* was found by us in sea water, in brackish water and in supersaline water, for instance near Baranquilla (Colombia) in salinities from 7 to 41‰, NW of Maracaibo (Venezuela) in 11–39‰, and in the Cocorite Swamps of Trinidad in brackish water. Here they keep to the coastal area. In the Netherlands Antilles *P. sphenops* is found in fresh and brackish water, especially in rivulets. They are also common in freshwater "tankies" and ponds, which they reach from the sea during a flooding from torrential rains. The molly is also very common in sheltered lagoons and in the inner bays, especially where mangroves are present. Some of the lagoons are brackish in the raining season and supersaline in the dry season – others are supersaline almost the whole year through. Here, mollies are found in salinities up to 80‰, in exceptional cases even to 135‰ (Kristensen, 1969).

In Aruba, the molly is very abundant in the rivulets and tankies, in Spaans Lagoen, and in the saliñas in the NW part of the island. In Curaçao, the species is also abundant in the "Ansinghplas", a small freshwater lake in Groot Kwartier, and, after a period of heavy rains in many other (temporary) freshwater pools. The shallow parts of the inner bays and the lagoons are sometimes crowded with mollies. They are also present in all saliñas that are in open connection with the sea, and in one land-locked saliña (that of Cas Abau). In Bonaire, the molly has only once been found in fresh water – but the inland pools are rarely connected to the sea.

Along the coast, the molly is abundant in Lac and Lagun. One land-locked bay, Slagbaai, has an abundance of mollies in the parts where the salinity is less than 90%.

When comparing populations from different habitats, especially when the salinity is different, the morphological differences of the population are striking. Quite obvious is the difference in size: animals from the sea being very much larger than those from fresh water or supersaline water. Difference in size between specimens from salt and brackish water and from fresh water has also been mentioned for the Panamá population by MEEK & HILDEBRAND (1916, p. 328).

In our investigation we tried to solve the following problems:

- I. Do the molly populations from different environments possess morphological (e.g. meristic) differences that are significant? Are there any morphological differences between the so-called subspecies in Curação and Aruba?
- II. If morphological differences exist, are they inherited or are they phenotypical?
- III. Do populations from different environments show differences in their preference for the environment?

Part of the investigations were carried out by the first author during a half year stay in 1961–1962. The investigations were completed by the second author during his directorship of the Carmabi (1960–1964) and during a visit to the islands in 1965.

GENERAL TECHNIQUES

For meristic data mollies were collected in Curaçao, Aruba and Bonaire. For our experiments only Curaçao mollies were used. When taking fish samples water samples were collected in the same spot. Salinity was determined by Cl' titration. The animals were caught by a drag-net (meshes 0.5–1 cm) where possible. Otherwise, a dipnet or a small plastic fish-trap was used.

Fish from freshwater locations were put into tanks with tapwater.

Mollies from the sea were put in seawater. For the fish from supersaline water a rather concentrated brine (\pm 100%) was diluted to a salinity of 70%.

In order to obtain newly hatched fish, pregnant females were put in a spare tank with a small compartment separated from the rest of that tank by a wall with open slits, so that the newly hatched youngsters could escape from the voracity of their mothers.

The mollies were mainly fed on KenL Ration (dogfood) after the fatty parts had been removed. What remained in the tank was taken away after some time.

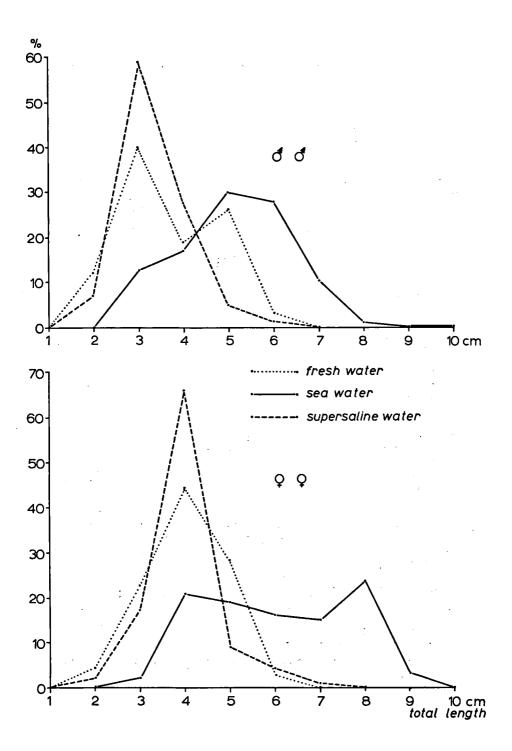
In small stagnant tanks the water was changed once a week.

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MORPHOLOGICAL DATA

In order to get an insight into the differences of total size some large samples of adult mollies were taken from the sea (Piscadera Inner Bay), from a supersaline lagoon (Cas Abau, salinity 70–75%), and from a freshwater lake (Ansingh-plas, Curação). The data have been plotted in Fig. 161. Immature specimens have been left out of consideration. Fig. 161 shows large differences, especially between the sea population and the two other groups. Considering the size distribution of the sea population it looks as if there might be two different year classes. This, however, is not true: most specimens, even the largest ones, were less than one year old. The sea mollies reach their maximum size within one year, in just the same time as the other populations. In the sea, the mollies grow more quickly than in fresh water and supersaline waters (see below). From the fact that the smallest (mature) fish in the sea population are larger than the smallest in the other ones it can be derived that the seawater mollies mature at a larger size than the others do.

Fig. 161. Size frequency distribution of mature fishes in localities of different salinities. Fresh water: Ansingh-plas, 231 \$\pi\$ and 508 \$\delta\$. Sea water: Piscadera Inner Bay (sal. 36%) 89 \$\pi\$ and 169 \$\delta\$. Supersaline water: Cas Abau saltpond (sal. 70%), 330 \$\pi\$ and 534 \$\delta\$.



More detailed data on meristics were obtained from smaller groups of adult fishes selected from various habitats.

The fish was obtained from the following locations:

Piscadera Inner Bay, Curação, salinity 34% Sta Martabaai, Curação, salinity 34-38% Saliña Cas Abau, Curação, salinity 70-75% Pond Curação Museum, salinity 0.1% Ansingh-plas, Curação, salinity 0.5% Rooi Bringamosa, Aruba, salinity 1.0%.

Measuring and counting was performed according to the methods used by MILLER (1948, 1955) and by HOEDEMAN (1959). The results have been tabulated in Table 5. The standard lengths are given in mm, and all other measures are presented in proportion to the standard length of the fish, in promilles. The data for males and females are presented separately.

The symbols used in Table 5 are the following:

number of fishes involved

Stl standard length (in mm)

Totl total length

Prdl predorsal length

Pral preanal length

Dp max. depth of body

Dcp depth caudal peduncle

Н head length E eye diameter

Sn from tip of snout to orbit

intraorbital distance (head width)

Mw mouth width

Finrays:

Scales:

D dorsal fin Lat along linea lateralis

A anal fin Tr transversal between D and A Prd predorsal, from top of the head to D

V ventral fin P pectoral fin

C caudal fin

In order to check the significance of the differences found the Standard Errors of Difference have been calculated. If the difference between two averages was more than three times the Standard Error of Difference this difference was considered to be significant.

The following significant differences have been found:

- A) Between seawater mollies from Piscadera Inner Bay and Sta Marta Bay:
 - 1) body-depth in Piscadera mollies is greater
 - 2) depth of caudal peduncle in Piscadera mollies is greater, but only in ♀♀

MORPHOLOGICAL CHARACTERISTICS OF POPULATIONS FROM DIFFERENT HABITATS

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ර්ර Piscadera	12	£	1322	585	200	331	219	270	62	88	136	%	8.8	1	0.9	14.9	25.6		9.3	14.6
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Enren Curação	41	ន	1310	603	526	285	174	315	8	99	146		8.4	1	0.9	13.7	24.9		9.0	14.9
Fresh Aruba	8	77	1319	290	518	300	185	321	8		143	8	8.1	i	0.9	13.8	25.0	27.4	9.1	14.9
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BRINE Cas Abau	31	30	1282	633	634	315	182	289	23	65	146	96	8.9	9.5	0.9	14.1	24.5	26.5	9.1	15.1
Curação	45	%	1266	621	638	265	158	319	89	49		8	8.2	9.0	0.9	13.0	24.0	27.2	9.1	15.0
FRESH Aruba	ଷ	31	1270	626	637	267	160	317	86	65	146	96			0.9	13.2	24.1	27.1	9.5	14.9

- 3) intraorbital distance in Piscadera mollies is greater, but only in $\delta\delta$
- B) Between mollies from sea water (Piscadera Inner Bay and Sta Marta Bay) and from supersaline water (Cas Abau):
 - 1) body length in the sea is greater
 - 2) number of rays in the pectoral fin is greater in the sea
 - 3) number of rays in the caudal fin is greater in the sea
- C) Between freshwater mollies from Curação and Aruba: no significant differences have been found
- D) Between seawater and freshwater mollies:
 - 1) body length in the sea is greater
 - 2) depth of caudal peduncle is greater in the sea, but only in PP
 - 3) head is shorter in the sea
 - 4) eye diameter is smaller in the sea
 - 5) number of rays in the pectoral fin is greater in the sea
 - 6) number of rays in the caudal fin is greater in the sea
 - 7) number of lateral scales is smaller in the sea, but only in the females

Some of the differences found are the result of the difference in body length: the larger the animal the deeper the caudal peduncle and the smaller the head and the eye. If this is taken into account the most important differences between the populations seem to be: in the sea the mollies are larger and have more finrays in P and C than in supersaline and in freshwater, and the freshwater females have a greater number of lateral scales than the females from sea and supersaline water.

II

ARE THE MORPHOLOGICAL DIFFERENCES BETWEEN THE POPULATIONS INHERITED OR ARE THEY PHENOTYPIC?

This question might be settled by raising mollies from different populations in seawater as well as in supersaline and in freshwater. Body proportions, however, are heavily influenced by capativity so that no information could be obtained on this subject.

Finray and lateral scale numbers are not influenced by captivity as far as we know. One experiment has been done, however, which shows the reverse.

In 1965, a sample of mollies from the Piscadera Inner Bay was taken, part of which was preserved for examination, and another part (P) was put in a freshwater aquarium (in Holland). The finrays and the lateral scales of the freshwater offspring (F1) were counted, and another part of the offspring was put in a seawater aquarium. The finrays and scales of the seawater generation F2 were also counted.

Table 6

Meristic characters in three generations raised in sea or in fresh water

		Finray	average	Lat. Scale
	n	P	С	average
males				
P (Piscadera)	43	15.0	25.8	26.0
F1 (fresh)	40	14.2	25.6	26.4
F2 (sea water)	58	14.4	25.3	27.1
females				
P (Piscadera)	50	14.8	25.7	25.8
F1 (fresh)	61	14.1	25.6	25. 9
F2 (sea water)	82	13.9	24.9	27.0

n = number of data.

The results have been tabulated in Table 6. The finray numbers show a significant decrease in the offspring, and the scale numbers a significant increase, both in males and in females. Although the experiment fails to prove that the changes might be caused by the salinity, it does prove that the finray and scale numbers are not fixed but may be influenced by environmental factors.

Next question is whether, perhaps, the differences in size between the sea populations and the supersaline and freshwater populations are inherited characteristics or not.

It is well known that there are many environmental factors that

also influence the growth rate. In our raising experiments the following factors have been considered:

- A. salinity
- B. substances in the water, for instance dissolved organic matter
- C. oscillations of environmental factors
- D. food, both quantity and quality

A. THE INFLUENCE OF THE SALINITY

To test the influence of salinity upon the growth rate all the other factors had to be kept constant as far as possible. The growth rate has been tested in stagnant water as well as in current water.

In the stagnant water series small aquaria of $1\frac{1}{2}$ l were used. They were filled with sea water (36%), with supersaline water (70%) or with tap water. The tanks were aerated constantly. In each aquarium 6 newly hatched mollies from the same litter were put together. If one of them died it was replaced by another from the same litter, which had been kept under the same circumstances.

The young ones hatched in sea water were divided into three groups that were raised, respectively, in sea water, in supersaline water and in fresh water. The same was done with hatchlings from fresh water. Mollies in supersaline water gave litters, the young however never survived. Although they had the same length (8–9 mm) as the freshwater and seawater litters, they were meager and their fresh weight was 14% less than that of the others.

The young were measured every two weeks. As it proved to be difficult to obtain reliable data when the animals were left in their tanks they had to be moved from the aquaria and were put on wet filter paper just for a few seconds to be measured. This method was found to have one disadvantage: small lesions of the mucous layer repeatedly caused fungus infections, some of which were fatal.

As several couples of fish could be raised in each series the growth rates have been averaged. They have been plotted in Figures 162–166.

Natural growth rate has been studied in a lagoon (along the Rifweg), which was drained by the tides through a wall of coral debris.

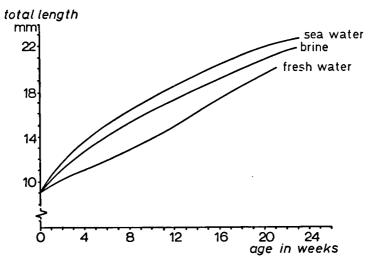


Fig. 162. Growth curve of hatchlings born in sea water and raised in water of a different salinity.

Here, a litter of about hundred youngsters could be observed during a period of 7 weeks (Fig. 164).

We do not have a picture of natural growth in brine or in freshwater, but in one experiment some youngsters were put in a rainwater tank of $1\frac{1}{2}$ cubic m (Fig. 166).

In Fig. 162 it is clear that hatchlings born in sea water have a faster growth rate in sea water than in brine or fresh water. The same holds true for hatchlings born in fresh water (Fig. 163).

When mollies born in sea water and others born in fresh water both are raised in sea water or brine they do not show the same growth curve (Figs. 164–165): the sea-born ones have a quicker start, but after about four months they are equalled by the freshwater hatchlings, which seem to have been hampered by the transfer to higher salinities. If the fish is raised in fresh water there is little difference between the ones born in fresh water and in sea water. Therefore, the stress by transfer from sea water to fresh water seems to be less than the reverse.

It should be kept in mind that in these experiments growth was stunted. In Fig. 164, the natural growth rate in a seawater lagoon

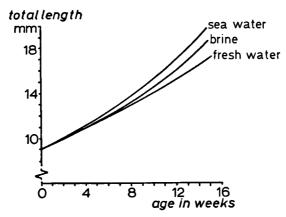


Fig. 163. Growth curve of hatchlings born in fresh water and raised in water of a different salinity.

has been added, and in Fig. 166 the growth in a large freshwater tank is shown. In stagnant aquaria it is only to be expected that growth is stunted. It is well known that stunting in crowded aquaria can be prevented by running water. Therefore, another series with running sea water and running fresh water was performed (Figs. 167–170). Here, growth proved to be better than in stagnant water, although it still was considerably less than under natural conditions. In this series again, it was seen that in sea water growth was faster than in fresh water (Figs. 167–168). Figures 169 and 170 show that it is of minor importance whether the juveniles were born in fresh water or in sea water.

From this, we may conclude that the differences in size between populations of different salinities may be caused, at least partly, by the differences in salinity and not necessarily by inherited differences in growth rate.

B. THE INFLUENCE OF ORGANIC MATTER ON THE GROWTH RATE

The question whether in this respect the amount of organic matter is important has not been studied separately. From the differences in growth rate between the experiments with stagnant and running water it may be concluded, however, that the increase of organic wastes is likely to hamper growth, as is also known from fish

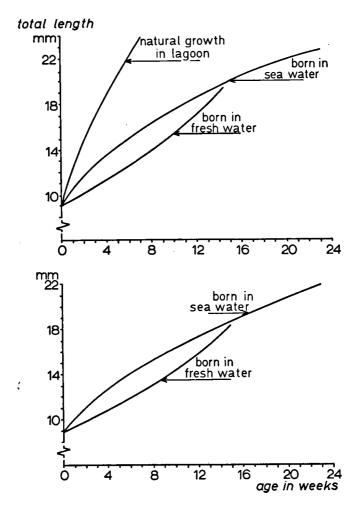


Fig. 164. Growth curve of juveniles all raised in sea water, one part being born in sea water but the other part in fresh water. The curve of natural growth (in a seawater lagoon) has been added.

Fig. 165. Growth curve of juveniles all raised in supersaline water of 70‰ one part being born in sea water, and the other part in fresh water.

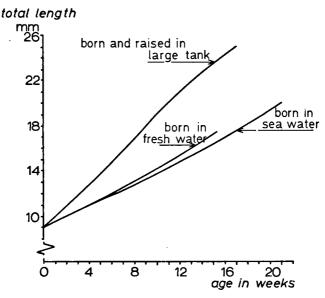


Fig. 166. Growth curve of juveniles all raised in fresh water, one part being born in fresh water but the other part in sea water. The growth curve in a large rainwater tank has been added.

farming. For the same reason, stunted growth will occur in all isolated places where crowding of fish is observed.

C. Influence of oscillations of environmental factors on growth

It seems rather unlikely that oscillations of environmental factors could be of importance, at least not in fresh water nor in the sea. Even in pools ("tankies") and lagoons the seasonal as well as the daily oscillations in temperature are small: in winter from 25 to 26°C, in summer from 27 to 31°C. In the inner bays and in lagoons the salinity is very constant, especially in years without excessive rainfall as was the case in the years in which our research was done. Oxygen oscillations may occur in small pools but the lagoons, the bays, the rivulets and the lakes are always around the point of saturation.

The only exception in respect to constant environmental factors

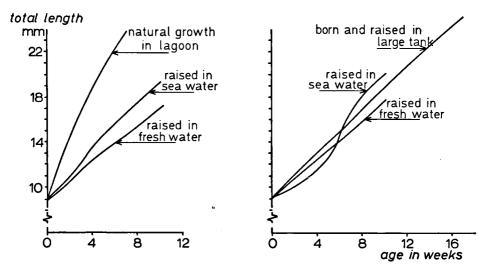


Fig. 167. Growth curve of hatchlings born in sea water, one part raised in running sea water, another part in running fresh water, and a third group in a sea water lagoon.

Fig. 168. Growth curve of hatchlings born in fresh water, one part raised in running sea water, another part in running fresh water, and a third group in a large rainwater tank.

is found in supersaline lagoons. Here, salinity may increase by evaporation or decrease by rainfall. Rain can bring along large changes in many respects: often a layer of fresh water is formed on top of the brine. This prevents cooling off of the deeper water layers where the temperature may rise to values far above 36°C which is lethal to fish, but the mollies may flee and find a refuge elsewhere. Although environmental oscillations may affect the density of the molly population, there is no proof that it should also affect the growth rate.

D. THE INFLUENCE OF FOOD ON THE RATE OF GROWTH

The stunted growth in stagnant water, both in fresh and in supersaline water, may partly have been caused by lack of food. In a confined area, only lack of food seems to keep down the population at a certain density. The offspring will for the greater part either starve to death or be consumed by the cannibalistic adults, the

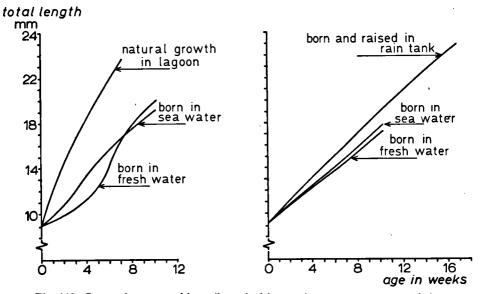


Fig. 169. Growth curve of juveniles raised in running sea water, one part being born in sea water but the other part in fresh water. The curve of natural growth in a seawater lagoon has been added.

Fig. 170. Growth curve of juveniles raised in running fresh water, one part being born in fresh water but the other part in sea water. The curve of growth in a large rainwater tank has been added.

latter phenomenon being more important than the former as we know from looking at the stomach contents. If the area has an outlet to the sea another food competitor is always found: Cyprinodon dearborni, a species that also can stand all salinities. Mollies and Cyprinodon fill about the same ecological niche: both have a preference for unicellular and other small algae, and both may eat plankton (also Artemia) when other food gets scarce. As long as there is a connection with the sea neither the molly nor Cyprinodon will vanish, but as soon as the habitat is cut off from the sea one of the two species will disappear. We know of only one exception: the land-locked part of Slagbaai, where both species are found, but in this case there is an abundance of food because of a constant, unceasing flow of Artemia from the saltiest part into the molly-area (KRISTENSEN, 1969).

Although the amount of food may influence the growth-rate, the differences between the populations cannot be explained by food supply only. When we compare a sea population with a freshwater one, from Ansingh-plas for instance, it seems improbable that shortage of food should play a role, as in both places the populations are kept down by predators: in sea by fish, in the Ansingh-plas by birds and *Diplostomum*-like trematods.

III

Do the "salinity-races" prefer different salinities?

Because of the density of mollies in supersaline as well as in fresh water it might be supposed that mollies avoid sea water. However, as has been mentioned above, the number of predators is numerous in the sea and negligible in supersaline and in most freshwater locations.

On the other hand, the fact that, after heavy rainfall, inland waters become densily populated with adult mollies, immigration from the sea points to an outspoken preference for fresh water, at least by mature fishes.

Another proof for preference by the adults for a certain salinity may be derived from the length – frequency distribution in an area with a salinity gradient. In many saliñas the majority of the juveniles is found in the part nearest to the sea, where the salinity varies from 40 to 50%. The adults, however, are more equally distributed over the whole area as long as the salinity does not surpass the 80% limit. An example of such a difference between mature and immature fish is given in Fig. 171. The two places where the samples were taken are at about 100 m distance, one being near the sea with a salinity of 42‰, the other showing a salinity of 73‰. Of course, it might be that the salinity influence is only an indirect one and that the differences in distribution are caused by food preferences but, nevertheless, it seems worth while to study the preference for salinities in juveniles and in adults separately.

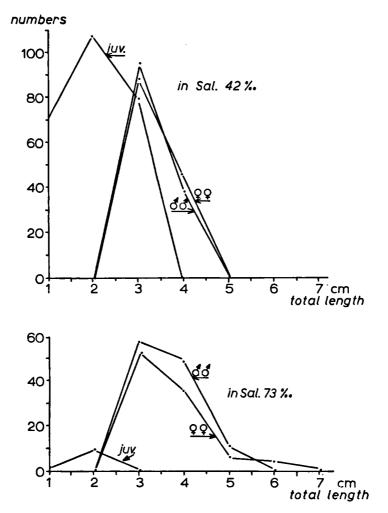


Fig. 171. Size frequency distribution of juveniles, males and females in two different parts of the saltpond of Cas Abau, one part of lower salinity (42%) and the other of higher salinity (73%).

Looking for the various abiotic factors that could be of importance we have to study:

1) preference for a certain salinity

- 2) preference for organic compounds in the water
- 3) preference for currents (positive rheotaxis, for instance)

1) Preference for salinity

Salinity preference was tested by means of the techniques used by BAGGERMAN (1958).

Small aquaria of $1\frac{1}{2}$ l were divided into two compartments by a glass wall that did not reach to the rim. The two compartments were filled with water of different salinity. The water at both sides was aerated during a whole night. Before the experiments were started a thin layer of fresh water was carefully added in order to give the fish the opportunity to move from one part into the other v.v. (Fig. 172). The

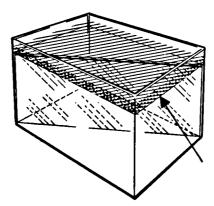


Fig. 172. Test aquarium. - Arrow indicating layer of low salinity.

salinity was checked in both compartments before and after each experiment. It was found that the salinity was not essentially affected by the movements of the fish, not even when the fish was rushing to and fro incessantly. As only a single fish could be tested at the time a whole battery of aquaria was made (Fig. 173) with the necessary controls. The controls were filled, at both sides, with the salinity the fish was adapted to; this was to detect a possible preference for other factors, and it gave the

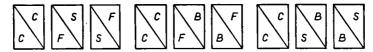


Fig. 173. Battery of three sets each containing three test aquaria. – F = fresh water, S = sea water, B = brine, C = "control" (that is the salinity the fish was adapted to).

fish the possibility to readapt itself to its normal environment before it was tested in another situation, as the fish passed through the whole series of aquaria of Fig. 173.

When a fish had been put into an aquarium it was allowed to settle during 5 minutes. Then, during 15 minutes, each 30 seconds it was observed to see in which of the two compartments it was present. Tested were all categories of juveniles used in the experiments of growth (juveniles born in different salinities and raised in fresh water, in sea water or in supersaline water). Moreover, adults from different environments, whether adapted to other salinities or not, were tested in the same way. Altogether, some 35.000 data were collected (Tables 7–10).

Table 7 shows that *freshwater hatchlings* if kept in fresh water (ff) always prefer fresh water; if they have to choose between sea water and brine they prefer sea water. When hatchlings born in fresh

Table 7

Preference of Hatchlings (f) born in Fresh water (F)

fs	= one da	antly kept i ay after bir r two days	th put into	sea water			
ratio of the environments preferred	1	F:S	(n)	F:B	(n)	S:B	(n)
Tested one	ff	65:35	(288)	64:36	(288)	71:29	(278)
day after	fs	29:71	(240)	90:10	(240)	83:17	(240)
transfer	fb	30:70	(240)	68:32	(240)	89:11	(240)
Tested 3-71	ff	74:36	(1550)	80:20	(1591)	65:35	(1520)
days after	fs	51:49	(1720)	74:26	(1680)	78:22	(1621)
transfer	fb	24:76	(1740)	52:48	(1650)	76:24	(1708)

water are transferred to sea water (fs), already one day afterwards they prefer their new environment (i.e. sea water) when tested. During the following days or weeks this preference becomes less clear although it remains significant as could be shown by the χ^2 test. If freshwater hatchlings are transferred to brine (fb) they never prefer their new environment, not after one day nor later on. When these brine fish have to choose between sea and fresh water they prefer sea water; this shows that some adaptation to higher salinities has taken place.

The preference of seawater hatchlings is shown in Table 8. When kept in sea water (ss) they prefer sea water, but when transferred to

fresh water (sf) they strongly prefer their new environment already after one day. When transferred to brine (sb) they go on preferring sea water, even after a stay of many weeks in the brine. When these sb youngsters have to choose between brine and fresh water they prefer the brine in the beginning, but later on their preference changes to fresh water. If they get the choice between fresh and sea water they prefer sea water. The significance of the preferences mentioned here has also been proved by χ^2 tests.

The general conclusion is that the preference shown by hatchlings for their own salinity environment changes by adaptation already

Table 8

Preference of Hatchlings (s) born in Sea water (S)

	ss = c	ne day afte onstantly k ne day afte	ept in sea	water (S, s	al. 35%)	‰)	
ratio of the environments preferred		F:S	(n)	F:B	(n)	S:B	(n)
Tested one	sf	76:24	(360)	79:21	(360)	91: 9	(360)
day after	\$ 8	36:64	(360)	59:41	(360)	64:36	(360)
transfer	sb	37:63	(360)	45:55	(360)	66:34	(360)
Tested 3-44	sf	72:28	(1440)	89:11	(1440)	72:28	(1440)
days after	SS	25:75	(1440)	83:17	(1440)	79:21	(1440)
transfer	sb	21:79	(1440)	63:37	(1440)	75:25	(1440)

Table 9

Preference of Adults (f) from Fresh water (F)

				resh water ater (S, sa			
ratio of the environments pref	erred	F:S	(n)	F:B	(n)	S: B	(n)
Tested (without transfer)	ff	67:33	(720)	73:27	(720)	52:48	(720)
Tested 1 day after transfer	fs	55:45	(600)	81:19	(600)	64:36	(600)
Tested 3-62 days after transfer	fs	73:27	(2160)	84:16	(2160)	77:23	(2160)

one day after transfer to another salinity environment. The preference for fresh water is somewhat stronger and longer lasting than that for sea water, and preference for brine of 70% is hardly or never attained.

From Table 9 it can be seen that *adult freshwater* mollies (ff) prefer fresh water, and if transferred to sea water (fs) their preference for fresh water considerably decreased after one day, but afterward the strong preference for fresh water returns – contrary to expectation.

In Table 10 it becomes clear that adult seawater mollies (ss) prefer seawater. After transfer to fresh water (sf) they prefer their new environment already after one day and that preference is not lost afterwards. These preference results proved to be significant.

Table 10

Preference of Adults (s) from the Sea (S)

			to fresh w cept in sea	ater (F) water (S,	sal. 35‰)		•
ratio of the environments pref	erred	F:S	(n)	F: B	(n)	S: B	(n)
Tested (without transfer)	SS	29:71	(720)	50:50	(720)	73:27	(720)
Tested 1 day after transfer	sf	58:42	(720)	63:37	(720)	58:42	(720)
Tested 3-24 days	sf	66:34	(1440)	83:17	(1440)	52:48	(1440)

The preference experiments with adult mollies show that the preference of the adults for fresh water is still more outspoken than in the hatchlings, and the adaptation to a new environment takes more time (3 days) in adults than in the juveniles (one day).

In order to exclude the possibility that not salinity differences should have caused the preference of the mollies, but differences in quality or quantity of dissolved organic matter one additional series has been done. Adult mollies had to choose between fresh water and sea water after both had passed a *Norit* activated charcoal filter (Table 11). The difference between the results if Norit filtered water and if unfiltered water has been used, proved to be insignifi-

Table 11

Preference of Adults born and raised in Fresh water

choice betw	reen	ratio	(n)
Norit filtered fresh water:	Norit filtered sea water	67:33	(104)
normal tap water :	normal sea water	63:37	(112)

cant. This excludes the possibility that in our former experiments the preference of the mollies for tap water or sea water might have been influenced by the presence of organic compounds.

Some details seem to be rather surprising, for instance that a fish from fresh water in its choice between sea water and brine does not reject the brine completely. Here, however, other factors might have come in: if the change of salinity is too great the fish gets perhaps distressed so that it does not choose "properly".

2) Preference for water rich in organic matter

The above mentioned results are in complete contrast to what has been found in elvers Anguilla (CREUTZBERG, 1961) and in Mugil (KRISTENSEN, 1964) which do not seem to be capable of discerning between sea water and fresh water. During their migration to inland waters they are not stimulated by salinity but by their preference for organic compounds in the water. Therefore, it seemed interesting to test the molly also in this respect.

In order to obtain water with a high amount of dissolved organic matter, water was taken from a little rain-pool, east of Schottegat. It was collected after a day of pouring rain; the water was very turbid, but it became rather clear after the mud had settled and the water had passed a paper filter. The amount of dissolved organic matter turned out to be relatively high, the KMnO₄ value being 14.5 mg/l, against zero in sea water and in tap water.

In order to obtain sea water with this organic matter brine of 70% was diluted with an equal quantity of pool water, giving a salinity of 35%.

Moreover, brackish water from the landlocked saliña Sint Marie (sal. 14%, KMnO₄ value 7.1 mg/l) was compared to sea water diluted by aqua dest to the same salinity of 14%. Supersaline water from the also landlocked San Juanbaai (sal. 46%, KMnO₄ value 8.7 mg/l) was compared to sea water condensed to the same salinity. In 1965, mollies were taken to Holland and were tested with respect to IJsselmeer water, which is strongly attractive to elvers (CREUTZBERG 1961); the IJsselmeer water had a salinity of 2% and a KMnO₄ value of 5.1 mg/l.

Table 12 Preference of Adults From Fresh water

choice between	ratio	(n)
pool:rain	90:10	(86)
pool tap: tap	88:12	(95)
pool sea: sea	77:23	(98)
pool sea: tap	57: 4 3	(111)
IJsselmeer: tap	92: 8	(100)
charcoal: tap	55:45	(153)

TABLE 13

Preference of Adults from Sea water

choice between	ratio	(n)
pool tap: tap	80:20	(92)
pool tap: sea	84:16	(99)
pool sea: sea	84:16	(43)
pool sea: tap	89:11	(54)
brack: dil. sea	92: 8	(100)
super: cond. sea	80:20	(101)

explanation of symbols
rain = pure rain water
pool = water from a rain-pool
tap = tap water
pool tap = 50% pool water and 50% tap
water
sea = sea water, sal. 35%
pool sea = 50% pool water and 50% brine
sal. 70%
charcoal = pool water filtered through
charcoal
brack = bay water sal. 14%
dil. sea = sea water diluted to 14%
super = bay water sal. 46%
cond. sea = sea water condensed to sal. 46%

Pure rain water proved to be unattractive when compared to rain water taken from a small pool. Pool water seems to be very attractive. The preference shown for pool or water mixed with pool water could proved to be significant by using the χ^2 test, with only two exceptions. In the test with a mixture (sal. 35%) of pool water and brine, against tap water the treshwater mollies did not make a significant choice (Table 12, pool sea: tap). Moreover, if pool water is filtered through Norit charcoal it loses its former attraction completely. In this respect the mollies show the same behaviour as young mullets (Mugil liza) do (KRISTENSEN, 1970). The attraction is not lost if pool water is changed into "sea water" by mixing with brine (Tables 12 and 13). Many types of inland waters seem to be attractive as well. Brackish water from an inland bay was significantly more attractive than diluted sea water (Table 13), and supersaline was more attractive than sea water condensed to the same salinity. One experiment was carried out in Holland: IJsselmeer water proved also to be extremely attractive just as it is to elvers. The organic compound causing the attraction has not yet been identified.

Between mollies from fresh water (Table 12) and from sea water (Table 13) no significant differences in preference are to be found.

3) Preference for running water?

From the foregoing experiments it has become clear that mollies can distinguish between waters of different salinities, and between waters with a different amount of organic matter. The experiments do not show, however, whether the fish has to find its privileged environment by trial and error, or that the fish is led by some concentration gradient. From the fact that mollies fanatically swim against freshwater currents it may be concluded that a positive rheotaxis could play an important role in directing the fish towards the inland. No experiments have been done, however, with respect to the role of currents either as a stimulus for the fish or as a guiding mechanism.

Discussion

It has been made clear that the molly populations from fresh water, sea and supersaline water have some small but significant morphological differences. These differences proved to be phenotypical. With respect to differences in growth rate similar results were obtained as by Kinne (1960, p. 297) who raised *Cyprinodon macularius* in fresh water, sea water and supersaline water: in sea water the growth rate is fastest, in fresh water slowest.

Many euryhaline species grow faster in the sea than in fresh water. The salmon species are a well known example. In general, the amount of food is considered to be important, but also changes in the osmoregulatory system play a role (osmotic stress influences the metabolic rate). In *Cyprinodon* (KINNE, 1960) the efficiency of food conversion was smallest when the metabolic rate was highest.

If, for mollies, growth rate is used as a parameter for optimal conditions the *sea* has to be considered the optimum environment. However, in our raising experiments and in the preference experi-

ments the adaptation from sea water to fresh water was faster than the reverse, which points to the possibility that mollies must be considered to be more at home in fresh water than in the sea.

Kinne (1960, p. 313) mentions that, in *Cyprinodon macularius*, the fry has a faster and more intense and partially irreversible adaptation to salinity changes if compared with the adults, and the same was found by us for the molly. Kinne suggests that this plasticity is correlated with a fast growth rate. Another correlation may be found with the rate of readjustment of specific weight: adjustment of the equilibrium is much quicker in hatchlings than in adult mollies. When young ones are moved from sea water to fresh water they tend to sink, but after six hours they do not seem to have troubles any longer. In adults, however, the troubles remain for at least twice that time or longer. No explanation can be given, however, for the fact that the "readjustment" of the preference some days after transfer decreases again during the weeks afterwards. Here, too, further investigations in metabolic rate and osmobehaviour should be carried out.

The salinity choice experiments with sea water and tap water throw no light upon the frantic endeavours of the adult mollies along the coast in periods of rain, struggling against the current of rivulets and temporary drainages in order to invade fresh water. The stimulus for this anadromous behaviour seems to be the same as in elvers and in other species (Kristensen, 1970).

Along the South American coast, *Poecilia sphenops* seems to be more or less confined to the coastal area, with fluctuating salinities (Mago Leccia 1965, p. 295). It may be asked why its rheotaxis does not bring the species up the rivers; in spite of their inland water preference they seem to be tied to the coastal environmental conditions. Perhaps the attractive compound is not present in sufficient quantities in the mainland rivers or at all.

In the small Antillean islands the population of moliles in the sea is small, probably because of the multitude of predators. However, this small population seems to be of utmost importance as it is a very stable one, in contrast to the populations of inland waters, both fresh and supersaline, which habitats seem to be more attractive than the sea. In the inland waters, however, mass mortalities occur because of adverse conditions, both of biotic and of abiotic nature.

Therefore the inland populations are subjected to occasional extinction, and the habitats have to be repopulated from the sea. This may be the explanation that no genetically fixed differences could be found between populations from fresh water, from the sea and from supersaline water.

SUMMARY

In the Netherlands Antilles, opposite the Venezuelan coast, the cyprinodont fish *Poecilia sphenops vandepolli* is found in fresh water, in brackish water, in the sea and in supersaline water. When comparing the populations from fresh water, sea water and supersaline water some significant morphological differences were found, e.g. in size, in depth of the body and of the caudal peduncle, in length of the head, and in the number of rays in the pectoral and caudal fins and the number of lateral scales. In raising experiments, however, it could be shown that these differences are phenotypic.

The characteristics of the subspecies or varietas arubensis as described by VAN LIDTH DE JEUDE (1887) proved also to be phenotypic.

Optimum growth was found in seawater.

The adaptation to fresh water after transfer from sea water or supersaline water is quicker than in the opposite direction; this concerns specific weight adaptation, growth resumption and the change of preference for the new salinity after transfer. With respect to these characteristics fresh water is more favourable than sea water or brine.

The inland migration after rainfall is not caused by the fresh water itself, but by an organic compound that is found in inland water, whether fresh or saline, and also in rain water after it has been in contact with the soil. From the fact that mollies also are attracted by IJsselmeer water, just as elvers are, it seems likely that mollies and elvers are attracted by the same organic compound. This behaviour of the molly causes irregular migrations from sea to inland waters which prevent the inland populations from developing into separate forms, races or subspecies.

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