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Studies on the Underwater Sound— VIII
Acoustical behavior of clownfishes (*Amphiprion* spp.)

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The acoustical behavior of seven species of clownfishes (Pomacentridae) bred in the tanks at Hubbs Sea World Research Institute was observed. Each specimen emitted some sounds composed of a pulse or a series of pulse sounds. These sounds were divided into three categories by their frequency components and, among of these species, some differences were found out. Each sound was relatively vigorous. The fish was utilizing these sounds for protecting their territory on their life, especially by some activities related with spawning or threat.

The mutualism between the clownfish (Pomacentridae) and sea anemone is already well known. A pair of adult clownfish forms a territory around the sea anemone and their movements are limited in this small area. The adhesive eggs of the fish are laid on the surface of a rock near the sea anemone. Usually, a pair of fish spawn and take care of eggs in their territory every month, however, the spawning took place more frequently in the laboratory as every two weeks. Female vigorously cleans up the spawning ground just before and after spawning. However after spawning, females of the most species of this genus hardly take care of eggs. On the contrary, males eagerly take care of eggs and do not go away from the eggs through the incubation period.

During a series of those behavior, they sometimes emit the sound. Verwey (1930), Schneider (1964) and Allen (1975) described already in their reports about the calls of some species of the fishes. Moreover, Verwey and Schneider suggested some assumptions on the sound production mechanism.

**Materials and Methods**

Currently a total of 27 species of *Amphiprion* spp. are known from the world. In the aquarium of Hubbs Sea World Research Institute, seven species among them, namely, *Amphiprion clarkii*, *A. polymnus*, *A. biculeatus*, *A. ocellaris*, *A. frenatus*, *A. melanopus* and *A. sandaracinos* are raised. Observations on acoustical behavior of these fishes were carried out.

These specimens had been reared in glass tanks of two sizes, 45 × 60 × 40 (depth) cm and 100 × 300 × 100 (depth) cm. The sand is placed 15 cm thick on the bottom of small tanks for filtration. A hydrophone was suspended at the middle depth in the center of the tank. A pair of clownfish was kept in each tank. Water and air supply were stopped during the recording to minimize the noise.

It was very difficult to record the correct frequency or duration of calls of fishes, because the tanks were small and no measure was adopted to lessen the reflection of sound. However, it seems that it is able to assume the relationship between their sound and behavior.

**Underwater Sounds**

The clownfish did not emit any sound when they were kept alone in the tank, however, they sometimes emitted some sounds when plural specimens were kept in a tank. The frequency of sound emitting increased in proportion to the number of fishes.
All of these sounds were constituted by pulse sound and had something in common with the main frequency component of less than 1 kHz. Moreover, most of the sounds were emitted singly with seldom exceptions of being emitted in a series. Accordingly, the pattern of sound was quite simple.

The sound with a long duration such as 0.056 – 0.065 sec was emitted rarely under the special behavior, however, the duration of pulse sound was usually 0.02 – 0.03 sec.

The components of frequency of sound were very various and all of sounds were divided into following three categories:

1. Sound containing the frequency component from very low frequency such as D. C. to several kilohertz, sometimes more than 8 kHz.
2. Frequency components limited between 200 – 300 Hz and a few kilohertz.
3. Sound composed of the frequency component of more than 1 kHz.

Moreover, each category was divided into 5 – 9 subcategories by fundamental frequency, harmonic and so on. However, the frequency of emitted sound was quite low under the normal behavior and most of all the frequency components were limited in low frequency less than 2 kHz and main frequency was about 500 Hz. The clownfish emitted the sound composed of single pulse or of a series of pulses. The latter sound was emitted by plural specimens that were staying close to each other and the sound of series of pulse was not heard when each specimen swam or stayed separately.

The clownfishes are taxonomically classified into two groups by the number of stripes of fish's body and the third category of sound were heard from the group of fish with more than two stripes on their body and were not heard from the group of fish with less than one stripe. Moreover, the high frequency and weak pulse sound such as popping were heard from every tank, however, it seems that those sounds were caused by nonbiological factor. Namely, the tank was divided into two parts (a part with fish and the other part with no fish) by styropone plate and same sound was heard from each part of tank.

Moreover, those pulse sound emitted by this species was rarely emitted before special movements as mentioned later and was usually emitted during or after the violent and special movement. Explanations of pulse sound of each species are given below:

1. *Amphiprion clarkii*

   Almost all sounds of this species were contained in the second category. Especially the frequency component were concentrated into 1 – 2 kHz (Fig. 1). The variety of sound of this species was very poor, however, the sound was emitted most frequently among the seven species described before. The both sounds of single and a series of pulse were emitted, and, in generally, single pulse sound was higher than a series of sound by about 300 Hz.

   Those sounds were heard from the fish not only when they were eating the food either suspending in water or floating at the surface of water but also when they were bathing in the sea anemone.

   In addition to this, the single pulse sound with the frequency component of more than 2 kHz was also recorded.

2. *A. polymnus*

   This species is large-sized one among the clownfish. The sound emitting of this species is very rare and the sound of the second category was not heard (Fig. 2). Those rare sounds were classified into three pattern. Namely;

   1. Pulse sound with the frequency component of 2.5 – 4 kHz and, sometimes, composed of 4 – 5 pulses.
   2. Single pulse and frequency component of D. C. – 4 kHz.
   3. Single pulse and frequency component of D. C. – more than 8 kHz.
All of these sounds had a strong component at low frequency.

The sound which was judging as the threatening sound from their behavior, was emitted from female, however, this sound was not special sound and was of the same pattern with the other sound and was emitted more strongly.

3. *A. biaculeatus*

This species is also larger one among the clownfish such as *A. polymnus* and the frequency of sound emitting was also low (Fig. 3). The fundamental or stronger frequency component of the most of sounds emitted by this species was low frequency less than 1 kHz (200–800 Hz : 200–600 Hz for D. C. –1 kHz sound, 400–800 Hz for D. C. –7 kHz sound).

Moreover, the sound which has frequency component from 5–8 kHz and has strong component at 6 kHz was very rarely heard, but, the source of this sound was not clear.

4. *A. ocellaris*

When the pair form their territory and live in a sea anemone, this species assume a conservative attitude and are always bathing in a sea anemone and hardly go away from it. Moreover, the sound emitting of this species is also not so frequent (Fig. 4).

These sounds were classified into three patterns by frequency range and pattern. Namely;

1. Single pulse sound with very narrow frequency range (1.25–2.8 kHz).
2. Low frequency sound composed of the frequency component of less than 2.5 kHz.
3. Sound with high frequency component of more than 3 kHz and, sometimes, make a series of pulse continued for about a second. Frequently, those sounds are heard during they are pecking
up on the surface of spawning ground.

In addition to this, the neutral sounds among the above-mentioned sound are heard from the juvenile tank. But, we can not distinguish the source of sound because several kinds of these fishes are living in the same tank.

5. *A. frenatus*

The frequency of sound emitting of this species is also not so high but following two types of sound were heard (Fig. 5). Namely;

1. Sound with stronger frequency component at 5–6 kHz.
2. Sound with stronger frequency component at 300–600 Hz.

This sound was, sometimes, composed of some pulses.

6. *A. melanopus*

The following two kinds of sound were heard from this species (Fig. 6). Namely;

1. Sound composed of a very wide frequency range (D. C.–8 kHz) without any stressed frequency components.
2. Sound composed of low frequency less than 1 kHz with stressed frequency component at 250–500 Hz.

It is very doubtful whether the former sound is caused by this species. On the other hand, the latter sound was often emitted in a series and a female used to emit this sound when it get out of a sea anemone, swims towards a male and stop just in front of the latter. Although this kind of movement was observed rather frequently, sound emitting was not recorded very often. And, sometimes, this type of sound was observed when a female bite a male at throat or abdomen to cause the latter cramping all over. After being bitten by a female, the male usually started to peck madly up the surface of a rock and emitted the sound.

While a vigorous sound during eating the feed was heard in other species, this species did not emit such sounds.

7. *A. sandaracinus*

The sound of this species was composed of single or a series of pulse sound with stressed frequency component at 300–600 Hz and were composed of less than three pulses with wide frequency range (200–3500 Hz) with two or three stressed frequency components (Fig. 7)

A fish dashed toward the other fish floated in water and the sound was, sometimes, recorded just
before passing each other.

Moreover, this sound was also recorded when two fishes were floating in water in parallel in such a species as *A. melanopus*. The same sound was not always recorded at the same behavior on each species.

**Acoustical Behavior during Reproductive Period**

Acoustical behavior during reproductive period was observed on *A. ocellaris*, *A. frenatus* and *A. sandaracinos*. The behavior of these fishes resembled each other. It was necessary to observe on every species, however, it seemed that the other species behaved as almost the same as above-mentioned three species judging from some brief observation.

It was easy to recognize the arrival of spawning period from the degree of fatness of abdomen and the projection of spawning duct of a female and these characteristic features became distinct three or four days before spawning.

They did not go away from a sea anemone and were bathing in it almost always. And the movement like "tail digging" was observed sometimes. From about 30 hours before spawning, this movement was executed vigorously and they became rubbing their side of belly against the rock near the sea anemone. This behavior, however, was not continued for so long a time and they began to behave like before. Moreover, they sometimes behaved in unusual manners, namely, going away from the sea anemone, pecking up the surface of the rock and going around as if they were looking for the spawning ground. A series of high frequency pulse sound became to be heard more frequently at 28 hours before spawning, but, it was not clear whether these pulses were emitted by this fish or not.

Female began to rub her abdomen against the rock (spawning ground) and cramp her body, and emitted a strong and low frequency pulse sound sometimes. This behavior lasted for 20 minutes, followed by a 10-minutes interruption. After repeating these movements two or three times, they rested in the sea anemone as before.

On the other hand, a male pecked the surface of rock and emitted a high frequency pulse sound sometimes. The pecking behavior was observed in a female as well. However, female pecked more frequently in earlier time, while male began to peck more frequently later. This movement was sometimes observed up to five hours before spawning but the remarkable change in behavior was not observed.

About five hours before spawning, female movement became dull and low frequency pulse sound which may be emitted by the female was heard frequently and gradually. High pitched sound which may be emitted by male were also heard sometimes. Pecking movement of a male on the surface of rock became vigorous from about two hours before spawning. This movement was continued until just before spawning. In case of *A. sandaracinos* this movement was carried out either simultaneously or alternately with the staying fish on the lookout for the disturbance. If they were disturbed, they stopped this movement and started to take a lookout in the sea anemone. Most of the disturbance had no effect on this behavior in case of *A. ocellaris*.

Just before spawning, the cleaning of spawning ground by pecking was more rigorously carried out by the female than the male. The female used to rub the tip of her spawning duct against the rock and pecked the surface of rock for 15 minutes before spawning, as if she was making sure of the completion of spawning ground. In case of *A. sandaracinos* this movement was not observed. Moreover, the male and female of *A. ocellaris* emitted individually the low or high frequency pulse sound just before spawning, then she began to spawn. However, these sounds were not so closely connected with spawning, because these sound were not always heard and were the same as usual sound. These sound were not heard from *A. sandaracinos*.

The spawning was carried out in the following manner: The female spawned and stucked the eggs in a queue, 3–4 cm in length, on the surface of rock; after a short rest she reversed and began to lay eggs
parallel and close to the first queue; this was repeated until the spawning ground, 4-5 cm in diameter, were filled with egg mass leaving a marginal space of 0.5-1 cm wide. After the spawning, female and male take care of eggs. Female became gradually less eager to take care of eggs. On the other hand, male and female of A. sandaracinos continued to take care of eggs.

From beginning to end of spawning, sound were hardly heard and A. ocellaris did not emit any sound for a long time after spawning. On the other hand, A. sandaracinos emitted continuously and constantly a weak and low frequency sound from the beginning of cleaning of spawning ground. However, it seemed that this sound was also not connected directly with spawning behavior.

**Threat, Attack and Acoustical Behavior**

There was relatively clear relationship between the sound and threatening behavior. The clownfish would drive away any invaders from their territory. It was observed in the tank of A. ocellaris that, cramping their body, they attacked and killed an invader. In case of A. frenatus, male and female, especially male, dashed and bit the invader and then, sometimes, cramp their body and emitted sound. All of sound were pulse sound, however, the sound that looked like threatening sound with cramping had a long duration (0.056 sec), a very narrow frequency range of about 500 Hz and with some harmonic.

These behaviors were continued until the invader got out of sight. At this time, female also behaved the same action, but not so actively. It was observed that female tried to bite male to get him back to spawning ground. Very high frequency sound was also rarely heard at that time, but the source of sound was not clear. A. melanopus also emitted the same threatening sound with a long duration (0.064 sec) and the sound had sometimes some harmonics. In this case, female bit the male at throat or abdomen and male emitted a series of pulse while male was cramping his body. The same sound were heard from male which was done the same attacks by female when male was madly pecking on the surface of the rock. The same sound was sometimes used for threat, although the degree of threat of A. polymnus was more vigorous.

A. clarkii emitted the vigorous threatening sound against the angelfish Holacanthus sp., which was put into the same tank. This sound was also a single pulse sound and had very wide frequency component (D.C.-8 kHz ≤) and moreover some of frequency component was lasting for more than one second depending on the resonance of tank.

Threatening sound was mainly emitted after the fish found the invader in near place, but threat was frequently carried out by some kind of sound. When we snap the wall of tank by a finger nail, we can make a strong pulse sound such as white noise resembling the sound of this fish. A. frenatus took a threatening behavior against this sound. Namely, they dashed, looked around and cramped their body and frequently emitted the threatening sound. When this stimulus was frequently given to this fish, the reaction became weak. However, when this stimulus was given after an interval, their threatening movement was provoked again. It seemed that this phenomenon was especially remarkable during a reproductive period and same phenomenon was observed also in A. sandaracinos.

In case of threat, it was most common to bite the invader, but the threat was sometimes carried out by means of the gesture (including the sound). These threatening movement was limited in their territory, but the sphere of these movement was reduced in case of a bigger invader.

Observing the behavior and each sound emitted by clownfish, it seemed that the pattern of sound was not so important and the meaning included in sound was variable by the circumstance when the sound was emitted and the way of sound projection (intensity, duration, repetition rate and etc.).

**Mechanism of Sound Production**

It seemed that the mechanism of sound production among clownfishes was similar, because the difference among sounds emitted was very little
and the movement during emitting sound was also similar. When we observed the movement of fish carefully during they were emitting sound, we could sometimes find out the special movement. This movement was mainly connected with taking food, consisting of a quick movement of mouth or opercle. Frequently, bubble was projected from opercle.

Teeth, air bladder and so on may be taken into consideration as source of sound, but it seems that these are not closely connected with sound projection as mentioned by Verwey (1930) and Schneider (1964).

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