Japanese Journal of Ichthyology
Vol. 22, No. 4 1976

魚類学雑誌
22巻4号 1976年

Notes on the Nesting Success and Fecundity of the Anemonefish *Amphiprion clarkii* at Miyake-Jima, Japan

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(Received June 26, 1975)

Abstract At Miyake-jima, *Amphiprion clarkii* spawns from May to September. Nesting frequency was 6~8 times per year. Incubation period varied from 6 1/2~13 1/2 days depending on water temperature. Fecundity was estimated 1,100~2,500 eggs per spawning and 8,000~17,500 per year. About 95% of nests were successful (eggs hatched).

Many species of the genus *Amphiprion* Bloch et Schneider have been studied in considerable detail (Verway, 1930; Fishelson, 1965; Allen, 1972; Mariscal, 1972; Moyer and Sawyers, 1973; etc.), but studies on the nesting success and fecundity of any of the genus are scarce. Allen (1972) reported on nesting and fecundity in *A. chrysopterus* Cuvier and *A. perideraion* Bleeker at Eniwetok, and Verway (1930) discussed the nesting success and fecundity of *A. percula* (Lacepède) in the aquarium. Fishelson (1965) makes passing reference to fecundity in his study of *A. bicinctus* Rüppell. Apparently little, if anything, is available on comparable studies of *A. clarkii* (Bennett). Allen's (1972) comprehensive book on anemonefishes makes no reference to such studies on *A. clarkii*.

The nesting success and fecundity of *A. clarkii* were studied at five separate locations on the small Japanese island of Miyake-jima (35°05′N, 139°30′E) from late in the breeding season in 1973 to the end of reproductive activities in 1975.

More than 100 hours of underwater observations using SCUBA were made on 34 pairs of *A. clarkii* at five study sites. Data were recorded on plastic slates. Daily records were kept on the nesting of three pairs of *A. clarkii* in Igaya Bay during the entire 1974 breeding season and on four pairs in the same location throughout the 1975 season. Three of the 1975 nesting pairs were the same fish that were studied in 1974, i.e. those at A-1, A-2, and C. Nesting pairs at other locations (Toga Bay, Sabigahama, Abe, and Okubo) were studied whenever possible, but only the Igaya Bay site, on the west side of the island, could be entered daily. This is due to the fact that it is sheltered from the prevailing SW, S, and NE winds of spring to late summer and from the typhoon swells of summer and autumn. The 34 nesting pairs under observation provided information on nesting frequency, incubation periods, nesting success, and fecundity.

Observations at some of the nesting sites in Igaya Bay are summarized in Table 1.

Results

a. Length of breeding season

In 1974, the first eggs of the breeding season were found on June 1 at all three nests in Igaya Bay and at one in the Okubo Cliff nest. Anemonefish eggs show marked change in color with embryonic development. Based on the egg color and water temperatures, it is estimated that the Okubo eggs were spawned on about May 26. Judging from the egg colors, the Okubo patch was older than the Igaya spawnings by 1~2 days.

In 1975, the first egg patches appeared two weeks earlier than in the previous year. The earliest records were two nests at Sabigahama where spawning took place on May 12. One nest at Abe and Igaya Nest B had new eggs on May 15. There is no definite explanation for the early start in the 1975 breeding season, compared to the 1974 season. Moyer (1975) found an identical situation in his study of *Pomacentrus nagasakiensis* Tanaka, and attributes it to an earlier full moon in 1975. This possibility should be considered. Natural variation, however, should not be discounted. Temperatures were comparable in both years.

In 1974, reproductive activity continued almost

Table 1. Spawning records of *Amphiprion clarkii* in Igaya Bay, Miyake-jima, 1974～1975. Estimated spawning date is marked with asterisk.

Nest	Date of spawning	No. of days since last hatching	Incubation period in days	Average temperature °C (approx.)
A-1	*5/29/74	?	10 1/2	—
	*6/10/74	1 1/2	10 1/2	—
	*6/25/74	4 1/2	10 1/2	—
	7/10/74	4 1/2	10 1/2	22.5
	7/27/74	6 1/2	8 1/2	24.0
	8/10/74	5 1/2	12 1/2	21.0
	*5/20/75	262 1/2	nest failed	—
	6/03/75	?	10 1/2	22.5
	6/18/75	4 1/2	13 1/2	21.5
	7/04/75	2 1/2	9 1/2	24.0
	7/17/75	3 1/2	9 1/2	26.0
	7/28/75	1 1/2	9 1/2	26.5
	8/10/75	3 1/2	nest failed	—
	8/23/75	?	6 1/2	26.5
A-2	*5/29/74	?	10 1/2	—
	*6/10/74	1 1/2	10 1/2	—
	*6/23/74	2 1/2	10 1/2	—
	7/13/74	9 1/2	10 1/2	23.5
	7/30/74	6 1/2	8 1/2	24.5
	8/09/74	1 1/2	nest failed	—
	9/03/74	?	6 1/2	25.5
	*5/29/75	293 1/2	10 1/2	—
	6/15/75	6 1/2	13 1/2	21.0
	7/02/75	3 1/2	9 1/2	24.5
	7/14/75	2 1/2	9 1/2	25.5
	7/24/75	1/2	10 1/2	25.0
	8/09/75	5 1/2	8 1/2	25.0
	8/22/75	4 1/2	6 1/2	26.0
	9/06/75	8 1/2	6 1/2	26.5
B	*5/17/75	?	10 1/2	—
	6/03/75	6 1/2	10 1/2	22.5
	6/20/75	6 1/2	12 1/2	21.0
	7/06/75	3 /12	9 1/2	23.5
	7/19/75	3 1/2	9 1/2	26.0
	7/31/75	2 1/2	8 1/2	27.0
	8/12/75	3 1/2	8 1/2	27.0
	8/23/75	2 1/2	6 1/2	27.0
C	*5/27/74	?	10 1/2	—
	*6/08/74	1 1/2	10 1/2	—
	7/01/74	12 1/2	10 /12	23.5
	7/19/74	7 1/2	9 1/2	23.5
	7/30/74	1 1/2	9 1/2	23.5
	8/21/74	12 1/2	8 1/2	24.5
	9/04/74	5 1/2	6 1/2	26.0
	*5/17/75	280 1/2	10 1/2	—
	5/31/75	3 1/2	10 1/2	23.0
	6/17/75	6 1/2	12 1/2	21.0
	7/03/75	3 1/2	8 1/2	24.0
	7/19/75	6 1/2	9 1/2	26.0
	8/10/75	12 1/2	8 1/2	26.0
	8/25/75	6 1/2	6 1/2	27.0

uninterrupted until Sep. 10, when the breeding season ended at Igaya. Daily observations were not possible in Toga Bay, but periodic checks showed that spawnings continued there for nearly another month, with the final hatching taking place on the night of Oct. 3. The reasons for the increased length of spawning at the Toga Bay site are not clear. Certainly water temperature is not a factor since temperatures ranged between 26～27°C at both sites.

Nesting ended at Igaya in 1975 on Sep. 12, when the eggs at Nest A-2 hatched. The last nest in the 1975 season, however, hatched on Sept. 23 at Sabigahama. The water temperature at this time was 27°C.

b. Nesting frequency

Due to frequent large SW swells at the other study sites, only the Igaya Bay nests gave sufficient data for estimating nesting frequency. In 1974, the nesting pairs A-2 and C reared 7 successful clutches of eggs, while A-1 tended 6 (see Table 1). It is possible that the C nest contained an eighth spawning since there was a 13 day lag in data on this nest while the author was on a trip. This is the longest nesting lag recorded for the three Igaya nests in 1974. Due to the timing of 'old' and 'new' egg patches at the other Igaya nests, it is certain that no additional spawnings took place during my absence.

In 1975, three of the four Igaya nests contained eggs eight times between May and September. The fourth contained seven clutches (see Table 1). Reasons for increased nesting frequency in 1975 are not clear.

c. Incubation period

Incubation period varied from 6 1/2 days on one occasion each in 1974 at A-2 and C and, in 1975, once each at A-1, B, and C and twice at A-2, to 12 1/2 days at B in 1974 and 13 1/2 days at A-1 and A-2 in 1975. In the seven 6 1/2 day examples, temperatures ranged from 26.5～27.5°C. The 12 1/2 day period at A-1 was in the midst of a long period of cold water which varied from 19～23°C for the first ten days of incubation, then rose abruptly to 26°C, after which the eggs quickly developed silver tips and hatched. A-1's and A-2's 13 1/2 day incubation periods began when the eggs were spawned in 24°C temperatures on June 18 and June 15, respectively. Temperatures stayed above 22°C until June 21, when the temperature dropped to 20.5°C. By this time A-2's embryos were fairly developed, with the eyes showing through the egg cases. The water remained cold for the next few days, reaching 16°C on June 25. The temperature rose above 22°C on June 28, and the eggs at A-2 hatched that night. A-1's eggs developed similarily and hatched on the night of July 1. It is interesting that the cold temperatures only retarded development and that all eggs hatched shortly after waters warmed again.

With the exception of the cold water damselfish, *Hypsypops rubicunda* (Girard), this seems to be the longest incubation period so far recorded for any pomacentrid (Clarke, 1970; Allen, 1972.) The influence of water temperatures on incubation periods is shown in Fig. 1. In some

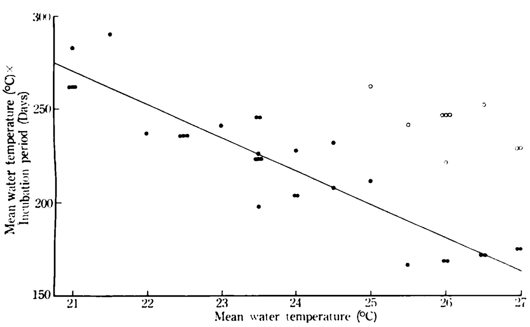

Fig. 1. Incubation periods of *Amphiprion clarkii* at different water temperatures. Points indicated with "O"=incubation periods that appear to be too long for the indicated water temperatures (see text for possible explanation). Linear regression "fit" of "●" points with 85% coefficient of determination.

instances, incubation periods appear unusually long for temperatures recorded. Reasons for this are not clearly understood, but may be related to invasions of cold water with incoming tides, an occasional phenomenon in Igaya Bay. Mean water temperatures shown in Fig. 1 were based on records from a single dive daily, and do not reflect fluctuations within a given 24 hour period.

d. Fecundity

Fecundity was estimated by the following method: several isolated egg patches, where only a single male and female were present, were collected. A hammer and chisel were used to break off the portion of volcanic rock where the eggs had been laid. The eggs were taken to the laboratory for counting. Counts ranged from approximately 1,100~2,500 eggs. Not all egg patches are the same size, some being considerably larger than others, even at the same nest. Such variation in eggs per spawning does not appear to be associated with water temperature or the time of year, but, rather, varies at random. Large and small egg patches have been recorded throughout the season and in both cold (22°C) and warm (27°C) temperatures. Taking this variation into account, fecundity for *Amphiprion clarkii* in Miyake waters, with 6~8 spawnings per year, is estimated to range from approximately 8,000~17,500. Since the smallest egg counts came from nests with eggs in advanced stages and had been thinned out by the male's removal of dead eggs, actual minimum fecundity may be higher than 8,000.

e. Failure of nests

Of 58 patches of eggs examined in 15 nests in 1974, only three were definitely known to have failed. 94.8% of nests under observation were therefore successful. It is interesting that two of the three unsuccessful nests were situated under the discs of *Stoichactis haddoni* (Saville-Kent). Two out of six egg patches occurring in *S. haddoni* nests (33%) failed. By contrast, only one of 52 egg patches (1.92%) in nests protected by *Parasicyonis maxima* (Wassilieff) or combinations of *P. maxima* and *P. actinostoroides* (Wassilieff) failed. Both of these anemones are endemic to Japan north of the Ryukyu Islands (Uchida et al., 1975).

Reasons for the failure of the three nests can only be imagined. Frequently, an unidentified species of clingfish (Gobiesocidae) was observed, taking advantage of the temporary absence of the defending male, to nip small numbers of eggs from the fringes of the patch. During dives in the early morning and at dusk, numerous individuals of *Thalassoma cupido* (Temminck et Schlegel) and *T. amblycephalus* (Bleeker) were often observed continuously moving over and through the anemones. Smaller numbers of *T. lutescens* (Lay et Bennett) were also observed at such times. Juveniles of all three species, and more rarely *T. lunare* (Linnaeus), were commonly seen living under the apparent protection of these anemones. On two occasions, *T. cupido* was observed eating the eggs of *A. clarkii*, but on both occasions the anemonefish had been disturbed by our observations. *T. cupido* was frequently chased by *A. clarkii* males defending eggs. *T. lutescens* has been observed eating the eggs of *Abudefduf sexfaciatus* (Lacepède) (personal observation), and it seems possible that various *Thalassoma* spp. may be responsible for the destruction of anemonefish nests from time to time.

In 1975, again three nests were known to have failed. These nests, however, were protected by *Parasicyonis maxima*. It may be useful to state that fewer egg patches were found in *Stoichactis haddoni* nests in 1975; therefore, a comparison between the two years would not be valid.

Discussion

Allen (1972) reported a fecundity of 3,000～5,000 eggs per year under natural conditions for *A. chrysopterus*, with a maximum clutch size estimated at 750 eggs. He further estimated *A. perideraion* to have a fecundity of 2,000～4,000 eggs annually, based on his studies of this fish under natural conditions. Verway (1930) gives fecundity of *A. percula* at about 5,000 eggs, but his studies were in the aquarium and may be misleading. Although Fishelson (1965) in his study of *A. bicinctus* does not actually state fecundity, his data on egg size and frequency and sizes of egg patches make it possible to estimate a fecundity at no more than 9,600 eggs annually. Allen (1972) places both *A. chrysopterus* and *A. bicinctus* in the 'Clarkii Complex', due to their close phylogenetic relationships to *A. clarkii*. Therefore, comparisons of these species with *A. clarkii* are of special interest. The Miyake population of *A. clarkii*, with 8,000～17,500 eggs annually, exhibits a considerably higher fecundity than any member of the genus *Amphiprion* studied to date.

A two month non-spawning period was noted by Verway (1930) for *A. percula* and Allen (1972) noted a five month rest period in the two Eniwetok species, but suggested the possibility of incomplete records during his absence from the island during that time. Allen reported 8～9 clutches of eggs during the spawning period at Eniwetok, and Verway (1930) reported 13 clutches for *A. percula* in a ten month period. Verway's aquarium studies represent an artificial environment, and therefore caution must be used in evaluating his data. Allen found that the average interval between clutches of eggs among Eniwetok species was about 30 days.

Our records with *A. clarkii* showed 6～8 clutches of eggs between May and October, with intervals between egg clutches ranging from 12 1/2 days to 1/2 day. Commonly, the interval between clutches was 5 1/2～7 1/2 days. The breeding season of *A. clarkii* at Miyake is therefore shorter and more intense than what is known for other species where comparable data is available.

Examples of *A. clarkii* nesting in tropical areas are lacking. Perhaps a comparatively short breeding season is characteristic for this species throughout its wide range. However, the possibility must be considered that cold Miyake waters from January to April may account for the short breeding season. Moyer's unpublished dive notes, 1970～1975, show great fluctuations in water temperatures at Miyake between summer and winter, varying from a maximum of 29°C in August and September to a minimum of 13°C in February and early March. The same six year source and my personal observations over a two year period show that many tropical Indo-West Pacific fish species, brought to the island as planktonic larvae during late spring to early autumn, are often either totally or nearly destroyed by cold winter waters, e.g. *Zanclus cornutus* (Linnaeus), *Chromis margaritifer* Fowler, *Dascyllus trimaculatus* (Rüppell), *Anampses geographicus* Valenciennes, etc. *A. clarkii*'s intensive summer reproductive activity may be a local adaptation to severe winter temperatures.

Acknowledgments

I would especially like to thank Jack T. Moyer, Director of the Tanaka Memorial Biological Station, who provided motivation, contributed many useful ideas, and continued the research during my short absence. A special thanks to Kathy Meyer and John Shepard of the TMBS staff who helped with many hours of observation. Other staff members who contributed include Marjie Carroll, Marco DiPaul, Peter

Johne, Mike Johnson, Claire Sawyers, Rita Springsteen, and Bruce Tulloch. I would also like to thank Dr. Hiro'omi Uchida of the Sabiura Marine Park Research Station, Kushimoto, Japan, for instruction in identification of sea anemones. Gratitide is expressed to Dr. John E. Randall, Bernice P. Bishop Museum, Honolulu, Dr. Eugenie Clark, Univ. of Maryland, Dr. Hitoshi Ida, Kitasato University, Dr. Teruya Uyeno, Luther Shingaku Daigaku, and Dr. Yoshiaki Tominaga, Tokyo University, for their helpful suggestions.

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三宅島におけるクマノミの営巣と卵生産能力

Lori J. Bell

クマノミは三宅島では5月から11月迄に産卵を行なう．1年に6～8回営巣し，1回に1,100～2,500，1年間に8,000～17,000個の卵を産む．産卵巣の約95％において卵は孵化した．

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