

## Aspects of the Reproductive Biology of the Wrasse, *Cirrhilabrus temminckii*, at Miyake-jima, Japan

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(Received November 24, 1982)

**Abstract** The reproductive biology of the wrasse, *Cirrhilabrus temminckii*, was studied at one of the Izu Islands, Miyake-jima, Japan during August and September, 1979. Most males at the study site were territorial while females occurred in "herds." Individual females migrated between male territories, indicating a promiscuous, but not necessarily random, mating system. The reproductive season at Miyake-jima was estimated to occur between May and September. Reproductive activity occurred in the afternoon and three pre-spawning actions were observed: flashing, rushing and looping. Only pair spawning was observed. Spawning tended to occur earlier as the time of sunset advanced. A relationship between timing of spawning and light intensity is suggested. Individual males were observed to spawn from 1 to 26 times per day. Interference spawning by a territorial, terminal-phase male is described. Initial-phase males are not believed to occur in this population. Male territoriality appeared to be based on the defense of territories for spawning-associated activities.

During the last decade the reproductive biology of numerous reef fishes has been studied in the warm-temperate waters around Miyake-jima (34°05'N, 139°31'E), one of the Izu Islands in Japan (reviewed in Thresher, in press). One species studied in passing was the labrid, *Cirrhilabrus temminckii* Bleeker (Moyer and Shepard, 1975). *C. temminckii* belongs to a genus of closely related, small Indo-West Pacific reef fishes. While *C. temminckii* from Japan is clearly defined, there is uncertainty in identifying similar *Cirrhilabrus* spp. from other areas of the Pacific (e. g., Marshall, Mariana and Fiji islands) as this species (Randall and Shen, 1978).

This species was locally abundant and its courtship and spawning conspicuous at Miyake-jima. Despite this, only limited work on this species has been published (Moyer and Shepard, 1975; Suzuki et al., 1977). Further observations were therefore made during August and September, 1979, to extend and, in part, quantify aspects of its reproductive behavior and general biology.

### Methods

All field work was conducted at Miyake-jima. Observations were made at Igaya Bay on the west side of the island. This specific study site was described in Tribble et al. (1982) and was located along the base of an eroded volcanic cliff running seaward for approximately 300 m. The

depth at the foot of the cliff increased seaward from 9 to 25 m. The substratum along the cliff base consisted of sand with overlying rocks and boulders and a few encrusting corals. The rocks were extensively overgrown by the red alga, *Gelidium* sp., and to a lesser extent, species of *Sargassum* and *Codium*.

During August and September, 1979, observations of *C. temminckii* were made daily except for 9 days due to inclement weather. Total observation time was approximately 100 hours. In the summer months the winds are light southwesterly, and the west side of the island is relatively calm. During the course of the study, however, two typhoons passed southwest of Miyake-jima, with the swells affecting Igaya Bay. This allowed observations of fishes during adverse conditions; however, it also prevented observations for several days. Strong tidal currents on two days also curtailed observations.

Temperatures were measured with a calibrated diving thermometer and field notes were recorded on plastic slates. Sunrise and sunset times, in addition to tidal and lunar cycles, were obtained from the Miyake weather station. Female fish were tagged using colored plastic beads, as described in Tribble (1982). Males could be readily identified by individual differences in color or morphology. A total of 23 females was marked during the study. Ten remained at

the end of the breeding season.

### Results

At Miyake-jima, *C. temminckii* is a mid-water zooplanktivore, ranging from 0.5~2.0 m above the bottom in areas of abundant shelter, e.g., seaweed and rocks. The species is sexually size dimorphic with males being larger, sexually dichromatic and monandric (sensu Reinboth, 1970; Suzuki et al., 1977), i. e., all males arise from females. During the reproductive season most males are territorial while females occur in foraging groups, or "herds" (Thresher, 1979). Such herds may also be associated with bottom feeding wrasses and juvenile parrotfishes.

**Sexual dimorphism.** *C. temminckii* is sexually dimorphic, such differences between the sexes include partial dichromatism (sensu Warner and Robertson, 1978). Color photographs of male specimens can be seen in Masuda et al. (1975) and Randall and Shen (1978). Males are easily distinguished from females, with their pelvic fins almost twice as long. In both sexes body coloration is maroon with turquoise along the lateral line, though the turquoise is usually darker

in males. This will be referred to as the lateral color stripe. Occasionally fish are seen that are intermediate in pelvic fin length and coloration. Moyer and Shepard (1975) suggest these individuals are in the process of sex change.

Males are also capable of temporarily altering their coloration. The turquoise along the lateral line widens and intensifies to an iridescent blue, then becomes a whitish green. The caudal fin ranges from maroon to an iridescent blue, to gold. Dorsal and anal fins also become bluish. The coloration varies according to the stage and intensity of courtship or agonism (Moyer and Shepard, 1975).

**Social structure and mating system.** Fishes could be readily assigned to one of three categories: territorial males, nonterritorial males and females. Six territorial males were observed routinely in the study area, all located intermittently along the cliff base. Male territory size ranged from 36 sq. m to 169 sq. m ( $\bar{x}=77.3 \pm 51.2$  (SE),  $N=6$ ). Territories were located linearly along the cliff, with two of them sharing a common boundary. Distance between male territories is indicated in Table 1. Each male

Table 1. Number of *Cirrhitilabrus temminckii* females, tagged with brown beads, observed on indicated days in a specific male territory. \*, date fish were introduced; Terr. width, width of male territory in meters; Dist. adj., distance between adjacent male territory boundaries in meters.

	Male territory number					
	#1	#2	#3	#4	#5	#6
Terr. width	13 m	13 m	13 m	13 m	8 m	15 m
Dist. adj.	0 m	7 m	5 m	47 m	1 m	
Date						
8/6	—	3*	—	—	—	—
8/7	—	8*, 1	—	—	—	—
8/8	1	2	—	—	—	—
8/9	—	6	—	4	—	—
8/10	—	—	5	—	—	—
8/11	—	4	—	1	—	—
8/12	—	6	3	—	—	—
8/13	—	6	—	5	—	—
8/15	1	5	—	4	—	—
8/22	—	1	—	—	—	—
8/23	—	1	—	—	—	1
8/27	—	5	1	—	—	—
9/1	—	4	—	—	—	—
9/2	—	4	—	—	—	—
9/8	—	2	—	—	—	—
9/14	—	4	—	—	—	—

territory encompassed the area usually occupied by one or two female herds. These herds ranged from 5 to 40 females ( $\bar{x}=18.7\pm8.8$  (SE),  $N=71$ ), but varied in size during each day. Such herds, as a group, appeared to remain in the same area, although no attempt was made to determine an entire group's daily movements. Occasionally male territories were seen without female herds. Marked females moved between male territories, individually or in small numbers (Tables 1, 2). 57.9% of the observations of marked females ( $N=38$  observations, classifying territory #2 and #5 as separate observations) resulted in at least one female in a territory other than where she was marked. The number of migrated females per observation ranged from one to five, averaging 2.05. The distance migrated ranged from adjacent territories to a maximum of 110 m (see Tables 1, 2). Occasionally solitary females were seen between territories. Females appeared to have home ranges encom-

passing more than one male territory.

The mating system present involves territorial males with females having larger home ranges. Multiple matings of both sexes without any apparent pair bonding suggests a promiscuous system. From the present data, however, it cannot be determined if these matings are random or nonrandom.

**Reproductive behavior.** Courtship behavior begins one to two hours prior to spawning with the male performing all displays. Three distinct actions were observed, termed flashing, rushing and looping.

Flashing appears to be a form of advertisement, in which a male swims near, or into, a herd of females while rapidly and conspicuously fluttering his caudal fin. Initially the flashing movement is slow, i.e., once every two to three minutes with each flashing pass lasting a few seconds. Body color is blue with a notably darker blue lateral color stripe. The blue fades

Table 2. Individual *Cirrhitilabrus temminckii* females, tagged with different color combinations, observed on indicated days in a specific male territory. \*, date fish were introduced; a, white-brown; b, green; c, white-green-brown; d, white; e, white-green; f, orange; g, orange-green; h, black-white; i, yellow-white; j, brown-yellow; k, brown-blue; l, orange-white.

	Male territory number					
	#1	#2	#3	#4	#5	#6
Date						
8/24 (10: 30)	—	—	—	—	abcde*	—
8/24 (15: 30)	—	—	—	—	d	a
8/25 (9: 00)	—	—	—	—	fg*	—
8/25 (15: 30)	—	—	—	—	abdefg	—
8/26	—	—	—	—	—	abdef
8/27 (8: 30)	—	—	—	—	—	ef
8/27 (15: 00)	—	—	—	—	e	f
8/28 (8: 15)	—	—	—	—	—	ef
8/28 (15: 00)	—	—	—	—	e	f
8/29	—	—	—	—	e	—
8/30	—	—	—	—	e	f
9/2	—	—	—	—	—	f
9/4	—	hijkl*	—	—	—	—
9/5	—	jkl	—	—	f	—
9/6	—	—	—	—	—	f
9/8	—	h	—	—	—	f
9/10	—	h	—	—	—	—
9/12	—	h	—	—	—	f
9/13	—	—	—	—	f	—
9/14 (10: 50)	—	h	—	—	—	f
9/14 (14: 30)	—	—	—	—	f	—
9/15	—	—	—	—	—	f

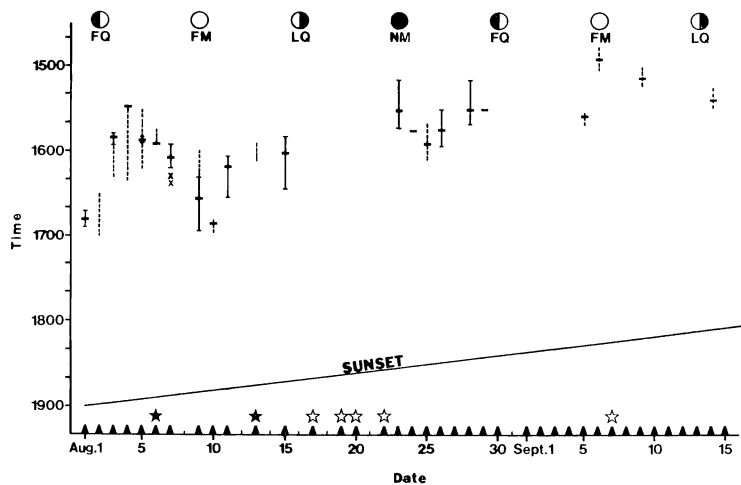


Fig. 1. Duration and timing of courtship and spawning by *Cirrhilabrus temminckii* during the study period relative to sunset time and lunar phase. Vertical solid bar indicates the time range during which spawning was observed on the indicated day, and the horizontal line indicates the mean value for the time of all spawnings during that day. Dashed lines indicate male courtship behavior and intense male courtship coloration. The two "x"'s indicate interference spawning of a terminal-phase male. Solid triangles show the days that the author was present at the study site during the reproductive period; closed stars indicate two days that these observations were curtailed by fast current, and open stars indicate <10 m visibility due to typhoon effects or rainfall runoff. Moon phases are indicated as follows: FQ, first quarter; FM, full moon; LQ, last quarter; NM, new moon. Time of sunset is shown by a solid line.

after each pass to the normal coloration. As courtship progresses, frequency of passes and swimming speed during flashing increase. Body colors become iridescent. Just prior to spawning, flashing is almost continuous with only a few seconds between passes. Body color becomes an iridescent whitish-green; most conspicuous is the rapidly fluttering caudal fin, which resembles shimmering gold.

As flashing increases in frequency, rushing begins. Rushing is defined as the sudden veering of a male towards a female during a flashing pass. In most cases, the male approaches from the rear.

Finally, just prior to spawning, looping occurs. Looping, a rapid ascent and descent reaching heights of 0.3 m, is performed rapidly and often in quick succession, near or within the female herd. Looping in *C. temminckii* is similar to that described for other labrids (e.g., Reinboth, 1973; Robertson and Hoffman, 1977; Thresher, 1979). Transitions between specific motor patterns are smooth; at this stage of courtship rushing and looping can occur in any sequence

and are connected by flashing passes.

*C. temminckii* was only observed to pair spawn (sensu Reinboth, 1973). Group spawning was not seen; however, it cannot be discounted. Spawning is a continuation of rushing, in which a receptive female, when approached from the rear by a rushing male, leads and together they proceed in an upward dash of about 0.1~0.3 m, where they quickly reverse direction and return to the herd. Gametes are released, usually in a conspicuous cloud, at the peak of the ascent. The spawning ascent is performed in one second or less. After spawning the male immediately continues courting other females.

**Spawning season, timing, frequency and termination.** The beginning of the spawning season was not observed in this study, but Moyer and Shepard (1975) reported their first observation of courtship on 13 May, 1974 and their last on 25 August, 1974. Suzuki et al. (1977) reported a reproductive season, in the warm-temperate sea of Suruga Bay where water temperatures are a few degrees lower than at Miyake, beginning in July and terminating in September. In the

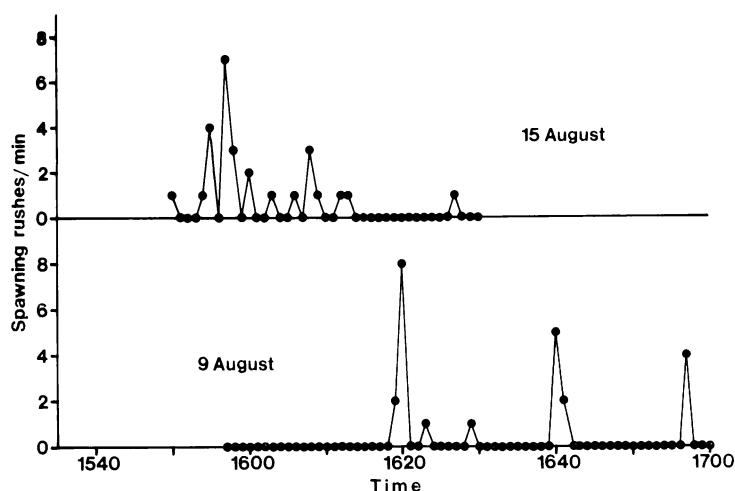


Fig. 2. Spawning rush frequency of a single male *Cirrhilabrus temminckii* on two different afternoons. Water visibility was greater than 30 m on August 9 and less than 15 m on August 15.

present study spawning was last noted on September 14, though observations continued through the month. This suggests a spawning season at Miyake-jima of roughly four months. Such a shortened season, compared to those of fishes in tropical regions (e. g., Robertson and Hoffman, 1977; Warner and Robertson, 1978) is typical of most species at Miyake-jima (e.g., Moyer and Bell, 1976; Meyer, 1977; Moyer and Yogo, 1982). I have observed a closely related species at Enewetak, Marshall Islands, spawning in both summer and winter.

During the cold winter months of January through March at Miyake-jima *C. temminckii*, if present, were cryptic. The following year they were first sighted in herds on April 26, 1980, when the water temperature rose above 20°C (Moyer, personal comm.). At this time fairly large aggregates were seen in almost the exact places as in 1979. One male was observed in fairly bright courtship colors flashing through a female herd in mid-afternoon (Moyer, personal comm.). The repetitive use of the breeding site may suggest that such are superior locations and represent a useful resource.

Reproductive activity occurred in the afternoon. Times of observed spawnings ranged from 14: 55 to 16: 57 (Fig. 1). This corresponds to 201 to 116 minutes before sunset, respectively. Day length was 14 hours on August 1, decreasing to 12 hours on September 13. Spawning tended

to occur earlier as the time of sunset advanced (Fig. 1). During August, the time of onset of courtship varied, occurring from one to two hours prior to spawning. In September it invariably occurred only in the hour prior to spawning.

Frequency of spawning varied both daily and among males. Spawnings/day/male ranged from 1 to 26 ( $\bar{x}=7.82\pm8.99$  (SE),  $N=11$ ). On August 9, for example, one male was observed to spawn 23 times in 38 minutes; on August 15, the same male spawned 26 times in 37 minutes (Fig. 2). Spawning often occurred in bouts, ranging from 1 to 8 spawnings/min for several minutes ( $\bar{x}=1.72\pm1.47$  (SE);  $N=65$ ). Such bouts were separated by as much as 26 minutes of limited activity (Fig. 2).

Frequency of spawning decreased notably after August 29 (Fig. 1). At this time only one or two spawnings were observed daily by specific males; some males did not spawn at all. Courtship of active males began no more than one hour prior to spawning; within five minutes of spawning the male would resume normal coloration and terminate courtship behavior. Female herds began to dissipate following the last day that spawning was observed. At this time, territorial males were often absent from their territories. A group of four males was seen on one occasion with a remaining female herd, however, neither courtship nor male-male aggression was observed. By September 29 fish were scattered

along the cliff base and the location of males and females varied daily. Individuals appeared in other parts of Igaya Bay, which were visited daily for other studies (see map in Tribble et al., 1982). Territorial and herding organization was not observed at this time with fish roaming freely. The behavior of *C. temminckii* remained as such until October 19, 1979 when Miyake-jima was hit by Typhoon 20 (See Tribble et al., 1982, for details). Surveys on October 21 indicated a 77% decrease in the abundance of *C. temminckii* individuals and a noticeable decrease in the *Gelidium* cover the fish used as shelter (Tribble et al., 1982).

**Male territoriality and aggression.** Not all males were territorial; approximately five non-territorial males were present and mobile within the study site. Territories were defended against all conspecific males at all times of the day, though with varying intensity. Territorial defense was observed on 5 out of 35 observation days (14.3%) during nonreproductive hours and 20 out of 43 days (46.5%) during reproductive hours. Similarly, the vigour of territorial defense by males declined toward the end of the breeding season. Defense occurred during non-reproductive hours on 4 of 24 days (16.7%) observed in August, but only 1 of 11 (9.1%) in September. Parallel data for reproductive hours were 16 of 25 days (64.0%) for August, and only 4 of 18 (22.2%) for September.

Intraspecific aggression was seen primarily between males. Behaviors ranged from ritualized displays to fighting. The aggressive display was observed when an intruding male entered the territory of a defending one. The "intruder" could be a nonterritorial male or a territorial one from an adjacent territory. Both fish swam towards one another, fins fully extended, in short dipping motions. Fin coloration was blue, except for the conspicuous long, white pelvic fins. If the intruder did not retreat, both fish developed a blue body coloration, with the intensity of coloration seeming to brighten as aggressiveness increased. Upon meeting side-by-side, approximately 5~10 cm apart, both fish would quiver their pelvic fins. One fish, then, often attacked another. Fish were also frequently seen chasing each other, along with head-to-tail circling and biting. Jaw locking was observed between fighting males on one morning.

The fish locked jaws head-on and remained stationary for 2~3 seconds, then continued chasing and fighting. This occurred twice, within minutes of each other. Moyer and Shepard (1975) also observed similar jaw locking once, between two transitional-phase fish. Color intensities associated with aggressive behavior ranged from "normal" to a bright, iridescent blue. The resident male became blue when chasing, and regained its normal color when being chased. Some intruding males developed a blue color when chasing. The iridescent whitish-green observed during spawning was never seen during fights.

Aggression between females was apparently rare, however Moyer (personal comm.) reported two females fighting and locking jaws on one occasion. Intersexual aggression was apparent only during reproductive hours. While courting, males would often chase individual females for short distances.

**Influence of environmental conditions.** Water temperatures during August and September ranged from 22.5°C~29.5°C, averaging 27.0°C. Spawning was observed at all temperatures within this range. Water clarity also varied widely, depending on the rainfall and water turbulence. Markedly reduced clarity conspicuously affected the behavior of *C. temminckii*; all were either found in the *Gelidium* or within 10 cm of the substrate, when water visibility was less than 5 m. Spawning was never observed under such conditions. Water visibility on August 9 was greater than 30 m, and less than 15 m on August 15. As mentioned, the highest number of daily spawnings were seen on these two days, however on August 9 it began 29 min later and ended 31 min later than on August 15 (Fig. 2). Light intensity would have been lower on August 15 than on August 9 at the same time of day. It is therefore suggested that light intensity may influence spawning time.

A relationship between spawning and the moon phase has been reported for several reef fish (e.g., Allen, 1972; Moyer, 1975; Johannes, 1978). Unfortunately, environmental conditions (e.g., low water visibility) after the last quarter moon phase (from Aug. 17, see Fig. 1) prohibited analysis of a lunar spawning cycle isolated from other factors.

**Other reproductive strategies.** Warner et al.

(1975) described two reproductive strategies, "sneaking" and "streaking", observed in *Thalassoma bifasciatum* (Bloch). Sneaking occurs when a small, nonterritorial male remains close to the territory of a larger male and individually spawns with gravid females in the vicinity of the ranking male. Streaking occurs when another male joins a male and female at the apex of a pair spawning. Both have been observed in *C. temminckii*.

On August 7 an adjacent territorial male (#1) repeatedly courted females from #2's herd. The #1 male had no female herd within his territory on this day. Although the intruder was frequently chased by the resident male, on three occasions when the resident was in courtship, the #1 male spawned with females from this neighboring herd. Sneaking was only witnessed on one day; however, resident males were often seen chasing intruding males during the reproductive period, suggesting it to be more common.

Streaking was observed once on September 9 (mentioned in Moyer, 1981). The intruding male was *C. temminckii*'s congener, *C. cyanopleura* (Bleeker), which is relatively rare at Miyake-jima. Three *C. cyanopleura* males were associated with different *C. temminckii* territories. On September 9 a pair of *C. temminckii* had begun their spawning ascent when the congeneric male dashed in and apparently spawned synchronously with the other two fish. Following spawning the resident male vigorously chased the intruder.

Ayling (1980) reported interference spawning (streaking) of male *Pseudolabrus fucicola* (Richardson) with spawning pairs of *P. celidotus* (Bloch et Schneider) in New Zealand, where neither species is rare. A basis for this behavior was not suggested. Moyer (1981), however, discusses the relationship between hybridization and scarcity of mates, and points out that interspecific pair spawning is more likely to occur between a common male and a rare female rather than the opposite. As a result, streaking with *C. temminckii* pair spawners may be the only possible mating strategy for *C. cyanopleura* males at Miyake-jima.

In that regard, interspecific aggression between *C. temminckii* and *C. cyanopleura* was observed frequently. Such chases, however, occurred only during spawning periods, especially when *C.*

*cyanopleura* would court females of *C. temminckii*. During non-spawning periods, courtship by *C. cyanopleura* elicited no evident response by either male or female *C. temminckii*.

**Predation on *C. temminckii*.** The dominant predator on labrids at Miyake-jima appears to be the lizardfish, *Synodus ulae* Schultz. This species has been observed to attack many species of wrasses at Miyake (Meyer, 1977; Tribble, 1982; pers. obs.), and during the course of this study, it was observed to make three unsuccessful attacks on *C. temminckii*. In all these cases the target was a male in conspicuous courtship coloration. Each attack consisted of the lizardfish rapidly darting up from the bottom toward the prey, then moving away. Upon attack, the wrasses darted into the seaweed, remaining there for about 30 seconds. The same response was observed when *S. ulae* swam about 2 m or less from a female herd. *S. ulae* is the only fish from which *C. temminckii*, and other wrasses associated with the herds, consistently fled.

Predation may also have affected survival of tagged females. There was a relationship between the color with which a female was tagged and the likelihood of seeing her again. Specifically, nine of 11 fish tagged in early August with brown beads, which blended in well with their body colors, were seen just prior to Typhoon 20 (19 Oct. 1979). In contrast, only 2 of 12 fish tagged in early September with a variety of colors could be found even two days after tagging. The difference between the groups in apparent survival is significant (Fisher Exact Probability Test,  $P < 0.01$ ). That survival is a function of bead color rather than some other factor may be supported by the color used on one of the individuals marked from the second group (Table 2). This fish was tagged with orange which is relatively cryptic underwater. The other fish was tagged with black and white. It is possible that the more brightly colored beads render a female more conspicuous in a herd or while sheltering in algae.

## Discussion

Reproductive behavior of *Cirrhilabrus temminckii* resembles that of most labrids studied to date (reviewed by Thresher, in press). Unlike many other wrasses, however, *C. temminckii* males have not been observed to "patrol"

individual territories (Thresher, 1979; Moyer and Yogo, 1982; Tribble, 1982; Colin, 1983). Because the female herds are relatively compact, behavioral actions appear to focus on the herd as a whole. Courtship with individual females is therefore not obvious but probably occurs in rapid succession, as does spawning during spawning bouts.

The intensity of male coloration varied both with the stage of courtship and between males (Moyer and Shepard, 1975). Contrary to their single spawning observation of *C. temminckii*, however, spawning did not appear to center around a prominent point, rather occurring wherever the female heard was present, as in, for example, *Halichoeres maculipinna* (Müller et Troschel) off Florida (Thresher, 1979).

Moyer and Shepard (1975) suggested a harem mating system for *C. temminckii*. However, data from the present study (see Tables 1, 2) indicate that mate fidelity did not occur. A harem polygynous mating system, by definition, involves at least a temporary pair bond or mate monopolization (Wilson, 1975; Emlen and Oring, 1977). Clearly, harem polygyny is not the case. Promiscuity, on the other hand, is broadly defined as multiple matings without a pair bond. As Wilson (1975) suggests, the present definition does not specify these to be random matings. The mating system of *C. temminckii* appears to be promiscuous, but not necessarily random.

The interference spawnings described for *Thalassoma bifasciatum* (Warner et al., 1975) involved small, initial-phase, nonterritorial males. It is of interest that the sneaking event observed during this study involved a large terminal-phase, territorial male from an adjacent territory. The promiscuity of the females appeared to force at least one less successful male, with no females in his territory at the time, to undertake this alternative reproductive strategy. Though sneaking was observed on one day only, aggressive interactions between territorial males were seen on several occasions, suggesting that sneaking may have not been uncommon.

In *C. temminckii*, territoriality appears to be based on the defense of a resource required by females, namely a choice location for spawning. Such territories may differ in quality as spawning sites due to the differential effect of the tidal cur-

rent along the cliff, and consequent differences in subsequent dispersal of gametes, e. g., Randall and Randall (1963), Leis and Miller (1976), and Johannes (1978).

Data to support the importance of spawning sites as critical resources are, of necessity, indirect. The principal food item, plankton, does not appear to be defendable. In addition, females do not defend areas, which might be predicted if food was in short supply. Female mobility also makes it unlikely that male defense is of specific female groups. And finally, reduced frequency of aggressive interactions during nonspawning parts of the day and abandonment of male territories after the spawning season both suggest spawning-associated activity to be the principal benefit of territorial defense.

Because no interference spawning by initial-phase males was observed at Miyake-jima, it is believed they do not occur in this population. The apparent monandry of *C. temminckii* does not preclude the occurrence of these males (Jones, 1980; Warner and Robertson, 1978), however, in other populations or under different conditions. Warner and Robertson (1978) and Warner and Hoffman (1980) suggest that a high ratio of females to terminal-phase males in dense populations, conditions apparently satisfied by *C. temminckii* at Miyake-jima (approx. 30:1, female: territorial male), promotes the presence of initial-phase males. Warner and Robertson (1978) have also argued that success by initial-phase males depends on their remaining anonymous in a group of females. Thresher (1979) has argued that a predictable spawning location, such as occurred in this study, also promotes their success. Although the reproductive behavior of *C. temminckii* at Miyake-jima appears to meet these criteria, it appears likely that the population does not follow theoretical predictions. The apparent absence of initial-phase males at Miyake-jima warrants further studies of the fish in other geographic localities.

The timing of spawning at Miyake-jima relative to sunset remained constant, suggesting that light intensity may be a cue for spawning. Observations were not made to determine if spawning occurred at equal light levels after sunrise. On days when water clarity was reduced spawning was notably earlier in the day (e.g., Fig. 2), an observation similar to those



made for fishes in other families (e. g., Moyer and Nakazono, 1978; Colin and Clavijo, MS). Colin and Clavijo (MS), studying the spawning behavior of a variety of reef fish off Puerto Rico, noted a consistent relationship between sunset time and timing of spawning for fishes in several families, including the labrid genera *Bodianus* Bloch and *Halichoeres* Rüppell. Such work has focused on evening spawning fishes, where changing light levels are conspicuous. It is therefore of interest that *C. temminckii*, as an afternoon spawner, may well be similarly influenced by light intensity.

#### Acknowledgments

I am grateful to the following people who helped in all aspects of the study: Dr. Hitoshi Ida, Gordon Tribble, Yutaka Yogo, Kunio Yoshimura and Martha Zaiser. I would like to thank the following people for their time and comments on various drafts of the manuscript: Drs. Jack W. Bradbury, Patrick L. Colin, John E. Randall, and Ronald E. Thresher. I would also like to thank an anonymous reviewer for many helpful comments. Lastly, I wish to express my sincere gratitude and thanks to Jack T. Moyer, Director of the Tatsuo Tanaka Memorial Biological Station, for his guidance, support and help during this study, and throughout the years; without it I never would have known the ocean. Contribution No. 45, Tatsuo Tanaka Memorial Biological Station.

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# イトヒキベラの三宅島における生殖行動

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イトヒキベラの生殖行動が伊豆諸島の三宅島で1979年 7~9月に観察された。ほとんどの雄はなわばり性を示したが、雌は群れを形成していた。個々の雌は雄のなわばりを移動し、生殖行動はランダムではないが乱交的であった。三宅島における生殖時期は5~9月と推定された。生殖行動は午後顕著になり、3段階の産卵前行動、即ち誇示、雌への突進、回転が観察された。産卵はペアで行なわれた。産卵時刻は日没が早くなるにつれて早くなった。産卵時刻と光の強さに関係のあることが示唆された。なわばりを持つ terminal-phase の雄による産卵行動の妨害も観察された。Initial phase の雄は本研究の個体群の中には見られなかった。雄のなわばり性は産卵にともなうなわばりを防衛する行動に基づいていた。