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Reef Channels as Spawning Sites for Fishes on the Shiraho Coral Reef, Ishigaki Island, Japan

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It is well known that channels in coral reefs that connect moats and lagoons with the open sea are ideal spawning sites for reef fishes that spawn pelagic eggs (e.g., Johannes, 1978). Spawnings at such sites are known to commence with the first noticeable ebbing of the tide (Johannes, 1978).

As a part of environmental research by the International Marinelife Alliance Canada and the International Union for Conservation of Nature and Natural Resources (IUCN) in response to a plan to construct an airport on the coral reef at Shiraho, Ishigaki-jima, Ryukyu Islands (24°34′N, 124°15′E), I was invited to undertake a study of important spawning sites within the Shiraho reef system. This paper reports my findings, and supplements my earlier work (Moyer, 1988).

Materials and methods

The study site. The Shiraho reef is one of the few healthy coral reefs remaining in Japanese waters (Muzik, 1985; Yasumoto, 1986). The reef contains at least 41 genera and more than 100 species of scleractinian corals, which serve as the habitat for more than 300 species of reef fishes (McAllister, 1988). Both coral and fish diversity is comparable to that of the Philippines, which is considered to be a center of biological diversity in the Western Pacific region (Wells, 1987). Four channels to the open sea are found along the 4 km length of the Shiraho reef. These are known by the following names: Nawabari, Bu-guchi, Moriyama-guchi, and Sumuji-guchi (also known as Ika-guchi) (Fig. 1). Moriyama-guchi, with a depth of 5 m and widths of 20–30 m, is the largest of Shiraho's reef channels. Another large reef channel, Touro-guchi, lies 3.1 km to the north.

It was hypothesized, following the work of Johannes (1978), that these reef channels would prove to be important spawning sites. Observations utilizing both snorkel and SCUBA were made on 4 and 5 October, 1987 (see Moyer, 1988), and daily from 26 April to 6 May, 1988. During surveys using SCUBA, I remained motionless at specific sites within the channel under study for varying periods of time and recorded species of fishes making spawning migrations, courting, and/or spawning. Modes of spawnings (see Warner et al., 1975) and spawning times to the nearest minute were recorded, according to species. Such a method required constant scanning of the surroundings at all sites and resulted in very conservative counts for any one species; i.e., observations of one particular species came at the expense of all others. Observations were made to coincide with the ebbing tide, however this turned out to be difficult due to the fact that wind direction and large ocean swells often produced drainage from the reef moat prior to high tide, i.e. during incoming tides, as water piled up inside the reef.

Surveys in April of all four channels in the Shiraho reef system disclosed that all were used by spawning fishes. The spawning site at Moriyama-guchi was by far the most impressive, and detailed spawning observations were made at that site.

Results

Spawning fish species diversity and spawning migrations at Moriyama-guchi. A total of 24 species, representing 13 genera and four families was recorded spawning in the water column at Moriyama-guchi during periods of outflowing water (Table 1). Of these, labrids were the most abundant, with 13 species, followed by scarids with five species and acanthurids and mullids with three species each. All observations of spawning mullids were made in October 1987 (Moyer, 1988). According to Shiraho fishermen, mullids begin spawning in late May or early June with the full moon. Thus, my 1988 observations were terminated prior to the mullid spawning season.

Of the 24 species observed spawning, all but the obligate coral polyp-eating labrid *Labropsis manabei* appeared to migrate to the spawning site strictly for the purpose of spawning, i.e. no feeding, resting, etc., was observed among migrating fishes. *L. manabei* males seemed to occupy permanent territories at the spawining site. It was not determined whether or not females of that species migrated to and from the site.

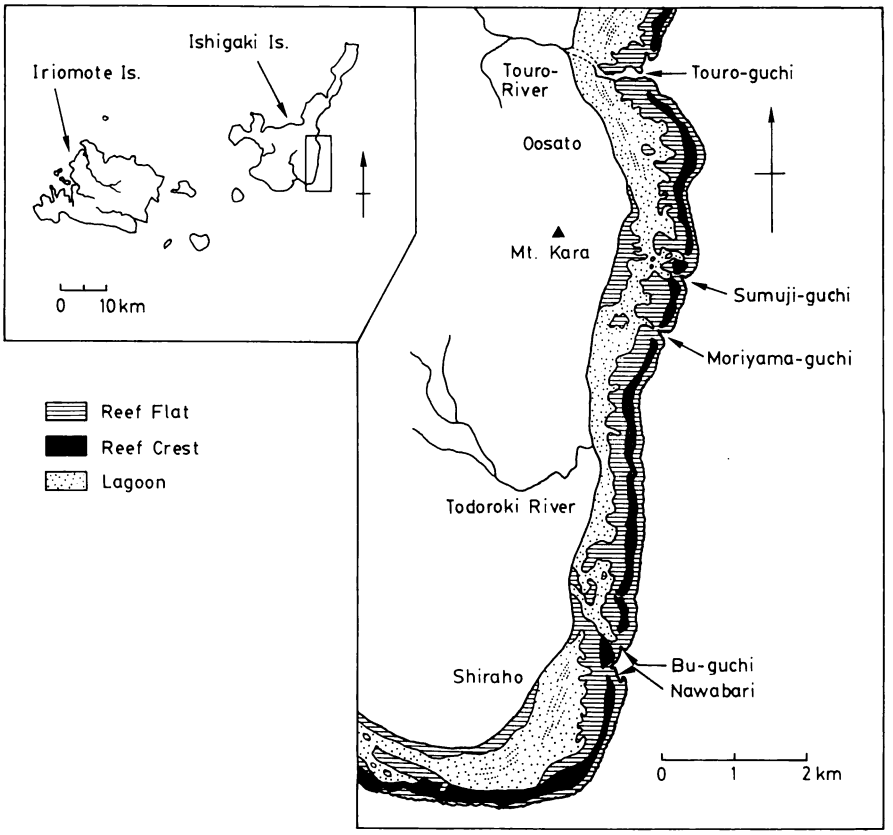

Fig. 1. Shiraho coral reef, showing reef channels.

Although limited numbers of the scarid *Scarus sordidus* were observed migrating to the Moriyama-guchi site from the north, such migrations were minimal, with by far the greatest number of individuals (estimated at about 90%) of all species approaching the site from areas to the south, i.e. the interior of the Shiraho moat.

Spawning periodicity at Moriyama-guchi. Spawning migrations seemed to commence at the onset of outflowing water from the moat to the open sea, regardless of the actual onset of the ebb tide. For example, high tide was at 15: 45 h on 26 April, but spawning migrations of scarids, especially *Scarus sordidus*, were observed as early as 12: 00 h, when the first slight signs of outward flow were detected. The first spawning (*Labropsis manabei*) was observed slightly more than one hour later, at 13: 17 h. A combination of large waves washing over the reef with the incoming tide, a strong wind from the SSE which pushed moat water northward in a moderately strong current, and a substantial input of fresh water from the Todoroki River produced outflowing water almost four hours before the onset of the ebb tide on this occasion.

Characteristically, spawnings were at a peak within 30–75 min after the onset of outflowing water, becoming noticeably less frequent by 150 min after the beginning of the outward flow. Table 2 shows frequency and mode of spawning for 10 species on 4 May, when outflowing water coincided with the ebb tide. Depletion of my air supply terminated the 4 May observation prior to the end of the spawning period. No spawning migrations were observed during incoming tides.

Other spawning sites. Limited observations were made at Nawabari, Bu-guchi, and Sumuji-guchi. Channels at the former two sites were shallow (2–3 m in depth) causing migrating fishes to pass through the channels to the open sea. Actual spawning sites were not found, due to strong SSE winds which prevented my access to

the open sea throughout the study. However, large numbers of scarids and acanthurids (especially *Scarus sordidus* and *Ctenochaetus binotatus*) were seen migrating to and from the open sea through the channel.

Observations at Sumuji-guchi (Ika-guchi) were made from the south side, where only minimal migration to and from the site was noticeable. Again, *Scarus sordidus* was the most common fish in the migrating groups.

Discussion

Clearly all four channels in the Shiraho reef serve as important spawning sites for a wide variety of reef fishes that release gametes freely in the open water. In addition to my underwater observations of courtship, spawning, and spawning migrations, Shiraho fishermen are quite familiar with the migration routes and spawning seasons of fishes in the Shiraho reef system. For example, both Bu-guchi and Moriyama-guchi were identified to me as important fishing sites due to the presence of spawning fishes when I first began my study in October 1987.

As Johannes (1978), Moyer (1987) and others have pointed out, such spawning sites permit fast dispersal of gametes away from the shallow reef waters where egg predators (especially Lab-

Table 1. Fish species observed spawning at Moriyama-guchi, Shiraho Reef, Ishigaki-Island, Japan. Total: 4 families, 13 genera, 24 species.

Family	Species
Mullidae	*Parupeneus barberinus*
	P. indicus
	Upeneus vittatus
Labridae	*Coris aygula*
	C. variegata
	Gomphosus varius
	Halichoeres marginatus
	H. trimaculatus
	Hemigymnus fasciatus
	Labropsis manabei
	Novaculichthys taeniurus
	Stethojulis bandanensis
	S. strigiventer
	Thalassoma hardwickii
	T. lunare
	T. lutescens
Scaridae	*Scarus bowersi*
	S. dimidiatus
	S. ghobban
	S. schlegeli
	S. sordidus
Acanthuridae	*Acanthurus dussumieri*
	A. xanthopterus
	Ctenochaetus binotatus

Table 2. Spawning frequency at Moriyama-guchi, Shiraho, Ishigaki-Island, Japan, 4 May 1988. Total: 10 species, 55 spawnings. High tide: 07: 53. *Group spawning (Warner et al., 1975); **terminal phase male streaking with terminal phase male/female (Warner et al., 1975); ***initial phase male streaking with terminal phase male/female (Warner et al., 1975). All other spawnings were male/female pairs.

Labridae	
Coris variegata	09: 23
Gomphosus varius	08: 38; 08: 51; 08: 52; 08: 53; 08: 59; 09: 11; 09: 16; 09: 24; 09: 26; 09: 26; 09: 27
Hemigymnus fasciatus	09: 02
Labropsis manabei	08: 40; 09: 28
Thalassoma hardwickii	09: 40
T. lutescens	08: 56
Scaridae	
Scarus bowersi	08: 32; 09: 31
S. dimidiatus	08: 40; 08: 45; 08: 48; 08: 54*; 09: 05*; 09: 06; 09: 15*; 09: 35
S. sordidus	08: 32*; 08: 32*; 08: 35*; 08: 37; 08: 38*; 08: 38*; 08: 45*; 08: 46*; 08: 46*; 08: 47*; 08: 49*; 08: 49*; 08: 50**; 08: 52***; 08: 53*; 08: 53*; 08: 54*; 08: 55*; 08: 57*; 08: 59*; 09: 05*; 09: 10*; 09: 16*; 09: 16*; 09: 16*; 09: 16*; 09: 27*
Acanthuridae	
Acanthurus xanthopterus	09: 35

ridae and Pomacentridae) are abundant.

Time and weather conditions did not permit quantification of spawning intensity or population density of migrating groups at each site, but clearly Moriyama-guchi was the most important of the four. Numbers of fishes migrating to and from the site were far greater than at other sites, and species diversity was considerably greater, i.e. 24 species spawned at Moriyama-guchi and only eight species were observed in spawning migrations at Buguchi, which appeared to be the most important spawning site at the south end of the reef.

Fishermen remarked on the importance of Sumuji-guchi as a spawning site, both for fishes and for squid. My observations at that site showed minimal migration from the south (i.e. from the Shiraho reef). If, in fact, it is a major spawning site, it is being used as such by fish populations from north of the channel.

It can be concluded that Moriyama-guchi is the most important spawning site in the Shiraho system, servicing pelagic spawners of at least four families from an as yet unknown portion of the Shiraho reef (presumably the northern half of the reef). Bu-guchi and Nawabari provide a less obvious, but similar site for the same species at the southern portion of the reef.

Spawning migrations were observed only during periods of outflowing water. No migrating fishes were present during comparative observations at Bu-guchi and Moriyama-guchi on incoming tides. Population densities, though not quantified, were conspicuously lower at the channels when the tide was flowing in.

Disturbances. Clearly any disturbance that greatly affects water visibility can disrupt spawning activity because courtship displays at the spawning sites are based on visual cues (see Robertson and Hoffman, 1977; Moyer, 1984). Construction along the Todoroki River has recently poured red soil into the Shiraho moat in the vicinity of Moriyama-guchi. Record rainfall on 28–29 April 1988 carried tons of red soil into Moriyama-guchi, bleaching hundreds of square meters of *Acropora* corals. Visibility was less than 1 m during that period and I was unable to work at Moriyama-guchi. It is unlikely that any spawnings occurred at that time. S. Ohgaki (pers. comm.) reported that by 25 June 1988 the bleached corals were, in fact, dead. The impact of such a disturbance on obligate coral polyp-eating species such as *Labropsis manabei* is obvious.

Both the original Shiraho airport plan and the revised plan, announced in April 1987 by the Environment Agency of the Japanese government, would interrupt access to and greatly pollute the spawning site at Moriyama-guchi, which is just off the southern tip of the newly proposed runway. Thus, airport construction would certainly greatly reduce the spawning success of thousands of fishes from the Shiraho reef, negatively affecting the quality of the very reef the Environment Agency is attempting to protect by their recent proposal, which would move the airport slightly north from the original site. Sumuji-guchi would be totally destroyed as a spawning site by the airport under the new proposal.

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石垣島白保地区サンゴ礁における魚類の産卵場所としての水路の重要性

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1987 年と 1988 年の両年，International Marinelife Alliance Canada と国際自然保護連合 (IUCN) に招かれて白保地区サンゴ礁における魚類の産卵場所を調査した．白保地区サンゴ礁では外海に通じる 4 つの水路が認められるが，そのうちのひとつ，モリヤマグチでは 4 科 24 種の産卵を観察した．その他の 3 水路では産卵は確認できなかったが，多くのブダイ類とニザダイ類が水路を通って移動しており，これらの 4 つの水路はいずれも浮性卵を産むサンゴ礁魚類にとって重要な産卵場所となっていることが明らかとなった．したがって，飛行場の建設に伴う水質の悪化はこれらの魚類の繁殖に大きな影響を与えるものと考えられる．

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