

論文の内容の要旨

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論文題目 **Reproduction, age, growth, and feeding habits of two co-occurring sillaginid fishes at Sikao Bay, southern Thailand**

(タイ国南部のシカオ湾に共存するキス科魚類 2 種の成熟, 年齢, 成長, および食性)

Sillaginidae is a commercially and recreationally important fish family in many Indo-West Pacific countries. In Thailand, however, the degradation of sillaginid fish resources has become a serious problem in recent years.

Two sillaginid species, *Sillago sihama* and *S. aeolus*, are widely distributed throughout tropical and subtropical coastal waters in the west-central Pacific and Indian oceans. In Sikao Bay, Trang Province, Thailand, preliminary observations indicated that these two species were the most dominant sillaginids, coexisting in shallow sandy areas throughout the year, although *S. sihama* was more abundant than *S. aeolus*.

Despite their abundance and popularity as food, little is known about the life histories of these fish, especially in tropical countries including Thailand. The objective of this study was to provide basic information on the biological traits of *S. sihama* and *S. aeolus* at Sikao Bay, by examining reproduction, age, growth, feeding habits, and juvenile seasonal occurrence.

Sikao Bay (7° 30' N, 99° 13' E) is a large bay, approximately 40 km long with a mouth width of 30 km, opening to the Andaman Sea. The bay has relatively short dry (January to April) and long rainy (May to December) seasons. Water temperatures at the sandy Rajamangala Beach in the bay ranged from 27.0 to 30.9 °C, but no seasonal trends were apparent. Adult and large juvenile specimens of *S. sihama* and *S. aeolus* were collected monthly from gill net fishery landings operated within Sikao Bay between May 2003 and April 2004. Gill nets (500 m wide, 1 m deep, and 25 mm × 25 mm square mesh) were set on the sandy bottom in the central area of the bay (water depth about 15 m) between 05:00 and 07:00 hours, and retrieved between 09:00 and 10:00 hours. Both species were captured during the same gill net operation. Small juvenile specimens of the two species were collected in the surf zone of Rajamangala Beach using a small seine net (10 m wide, 1 m deep, and 1 mm × 1 mm square mesh). This sampling was conducted monthly at flood tide (water depth about 1 m) between 6:00 and 9:00 hours from May 2003 to April 2004.

Reproduction

A total of 2,926 and 2,077 specimens of *S. sihama* and *S. aeolus*, respectively, were used to determine sex ratio, gonad development, spawning season, size at maturity, and lunar-related spawning patterns. The annual sex ratio (male : female) was 1 : 1.50 in *S. sihama* and 1 : 0.88 in *S. aeolus*, each being significantly different from the expected 1 : 1. Histological examinations of gonads showed that the smallest mature females and males in *S. sihama* were 117 and 106 mm in standard length (SL), respectively, and 113 and 109 mm, respectively, in *S. aeolus*. Body size at which 50% of individuals reached maturity (i.e., size defined as adults) was estimated to be 130 mm SL for both species and sexes. The lowest spawnable gonadosomatic indices for female and male *S. sihama* were 0.53 and 0.04, respectively, and 0.47 and 0.03, respectively, in *S. aeolus*. Spawning occurred continuously throughout the year for both species, with peaks in activity between August and November in *S. sihama*, and between July and December in *S. aeolus*. Oocytes at various developmental stages, together with postovulatory follicles, were found in the mature ovaries of the two species during their spawning periods, demonstrating that they are multiple spawners. Between June and August, both species at Sikao Bay showed a tendency for semilunar spawning cycles, with peak activity around the half moon, although this study was not conducted in other months.

Age and growth

Age and growth parameters of *S. sihama* and *S. aeolus* were estimated from sagittal otoliths of 285 and 317 fish, respectively. Whole sagittal otoliths were suitable for determining the ages of both species. The boundaries between translucent and opaque zones were clearly defined, 86 and 90% of the examined otoliths of *S. sihama* and *S. aeolus*, respectively, being readable. The observations of otolith edges showed that one annulus was deposited each year, with opaque zone formation occurring mainly in September and October for both species. The oldest *S. sihama* specimens collected in this study were 1.99 (157 mm SL) and 1.97 years (162 mm SL) for females and males, respectively, and 1.99 (200 mm SL) and 1.99 years (168 mm SL), respectively, for *S. aeolus*. The von Bertalanffy growth parameters of the two species were estimated for females and males separately, using length-at-age data. No significant difference was found in the growth curve between sexes in either species. Thus, the growth curve combined for both sexes of each species was as follows:

$$S. \text{ sihama} \quad L_t = 207.7 [1 - \exp \{-0.53 (t + 1.09)\}]$$

$$S. \text{ aeolus} \quad L_t = 190.6 [1 - \exp \{-0.81 (t + 0.54)\}],$$

where L_t is SL in mm at age t in years. These two growth curves were significantly different from each other.

Feeding habits

The feeding habits of juveniles (< 130 mm SL) and adults of *S. sihama* and *S. aeolus* were examined on the basis of 892 (127 juveniles and 765 adults) and 734 (159 and 575) specimens, respectively. The diets of juveniles of both species changed progressively with increasing body size, with a shift from capturing small zooplankton, such as calanoid copepods, to larger benthic prey, such as polychaetes, shrimps, and crabs. The latter three items were also the most important prey of adults of the two species, together constituting more than 70% of stomach contents by volume. Pronounced seasonal changes in adult diet were not detected in either fish species. In addition, considerable overlaps of juvenile and adult diets between the two coexisting *Sillago* species were found during the study period, indicating that there may be little or no competition between them at Sikao Bay.

Seasonal occurrence of juveniles

All specimens of *S. sihama* and *S. aeolus* captured in the surf zone of Rajamangala Beach were juveniles smaller than 130 mm SL. Monthly changes in the mean number of

individuals per haul (150 m²) indicated that juveniles of both species occurred at the beach throughout the year, with a peak abundance from November to January in *S. sihama*, and from January to February in *S. aeolus*. Moreover, the size frequency distribution of the two species revealed that most collected juveniles were small, less than 45 mm SL. The lengths of *S. aeolus* never reached 70 mm SL, and those of *S. sihama* rarely exceeded 70 mm SL. These results suggest that the two species display an ontogenetic habitat shift, from surf zones to offshore and deeper waters. Shallow nearshore habitats, including surf zones, may function as nursery areas for *S. sihama* and *S. aeolus*.

The present study showed that the overall biological aspects are very similar between *S. sihama* and *S. aeolus* at Sikao Bay. Both species typically had a high growth rate and short life span. The vast majority (> 80%) of individuals attained maturity at the end of their first year, by which time they were generally 130 mm SL or more, and all individuals died before reaching two years of age. However, this is far less than those of conspecifics and other *Sillago* species in different locations. This phenomenon, in addition to the continuous decline in the annual catch of *Sillago* in southwestern Thailand in recent years, suggests that *S. sihama* and *S. aeolus* at Sikao Bay have been overfished. Therefore, effective management should be implemented to reduce some of the pressure from the harvests of both species, before it is too late to save the stocks. Further investigation is needed to establish an appropriate management plan for *Sillago* fisheries at Sikao Bay.