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Notes on the Biology, Taxonomy, and Distribution of Flashlight Fishes (Beryciformes: Anomalopidae)

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Abstract New information concerning the distribution and biology of anomalopid fishes is presented. There are five valid described species: *Anomalops katoptron* and *Photoblepharon palpebratus*, widely distributed in the central and western Pacific Ocean; *P. steinitzi* from the Red Sea and Comoro Islands; *Kryptophanaron alfredi* from the Caribbean; and *K. harveyi* from Baja California. *P. steinitzi* differs from *P. palpebratus* in coloration, head bone ornamentation, and pelvic ray number. The second known specimen of *K. harveyi* is described in detail. The occurrence of large specimens of *Anomalops* in deep water and small specimens in shallow water is discussed. Synonyms and a key to the species of anomalopids are provided.

Boddaert (1781) was the first to describe an anomalopid, and named it the "Porgy with an eyelid". He proposed that the function of the subocular organ was to shield the eye from injury caused by contact with coral branches. Lacepède (1803) ventured that the peculiar organ served to protect sensitive tissue against sunlight. Günther (1876–81) first recognized its light-producing function, but it was not until 1900 that Vorderman finally saw the light. Since that time, a considerable body of research has centered around the bioluminescence and behavior of the Indo-Pacific species *Photoblepharon plapebratus* and *Anomalops katoptron*, particularly in Indonesia (cf. Steche, 1909; Harvey, 1922; Haneda and Tsuji, 1971).

There are five valid described species of anomalopids. The rarity of specimens and observations of anomalopids is a result of their deep reef daytime habitat, a difficult environment to sample either by traditional trawling or with rotenone ichthyocides. The nocturnal ascent of some anomalopids allows their capture along the reef, thus during the last decade, biologists using scuba equipment have nocturnally searched for and discovered populations of anomalopid species previously thought to be extremely rare (Morin et al., 1975; McCosker, 1977). It is likely that proper sampling techniques will show anomalopids to be more widely distributed. We have herein assembled many new records based upon our collections and other museum specimens, as well as communications with ichthyologists who have observed but not collected anomalopids, allowing us for the first time to present a more complete analysis of the taxonomy and distribution of the family.

Methods are those of Rosenblatt and Montgomery (1976). Fish length is recorded as standard length (SL), unless otherwise noted. The institutional abbreviations for the material examined in this study are listed in the Acknowledgments section of this paper.

Biology

Recent field and laboratory studies as well as the accumulation of specimens have shed new light upon the biology of the anomalopids. These advances, however, have raised further questions. Particularly puzzling is the apparent disjunct distribution in relative size and in depth of occurrence of individuals of *Anomalops katoptron*. Whereas the majority of the specimens of *Anomalops* that have been collected are between 35–80 mm SL and have come from shallow surface waters (0 to 10 m), several deepwater specimens (110 to 365 m) have been captured, and range from 232–266 mm SL. Takeshi Shimizu (in litt.) reports that the 14 *Anomalops* specimens from Japan are all large (127.5–185 mm SL) and caught in deep water (to 350 m). This size/depth relationship cannot be explained as a difference in reproductive state, in that both shallow water and deepwater individuals are sexually mature (e.g., see Harvey 1922, and our own observations). Such a bimodal depth and size distribution would appear to be unique among

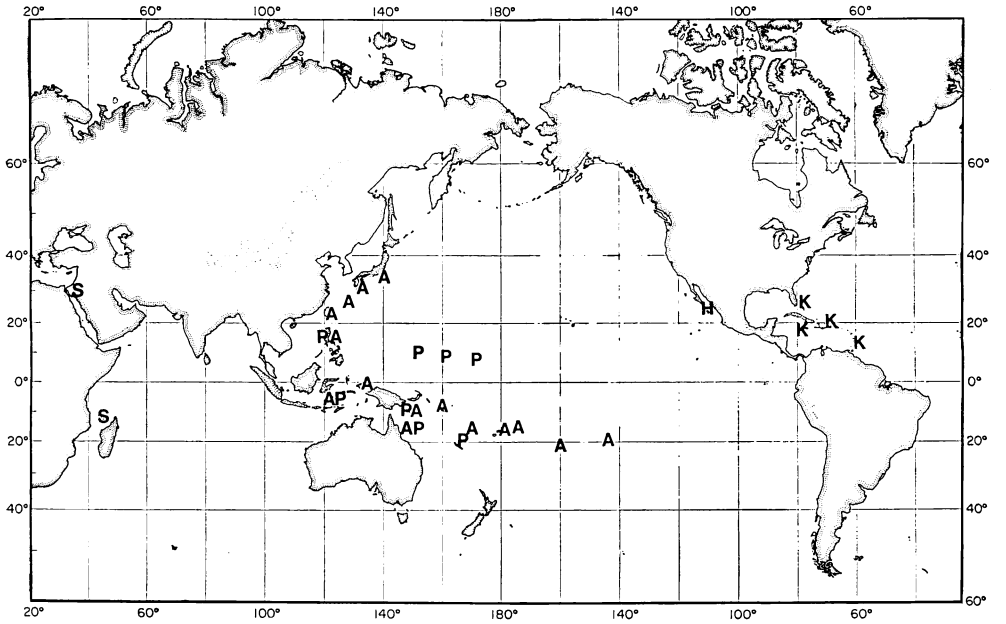

Fig. 1. Distribution of anomalopid fishes. A, *Anomalops katoptron*; H, *Kryptophanaron harveyi*; K, *K. alfredi*; P, *Photoblepharon palpebratus*; S, *P. steinitzi*.

nearshore deep reef fishes, but there are alternate explanations. It is possible that *Anomalops* matures at a small size and the restriction of large individuals to deepwater is merely an artifact of collecting methodology (thereby assuming that all deepwater specimens have been caught by hook and line and the smaller individuals have avoided capture). But such a pronounced size disparity is without parallel. Or, it may represent a sampling limitation, in that diver observations in areas where *Anomalops* lives in shallow water have been limited to such depths. We are unable to find any character that distinguishes the large form from the smaller form and they have been found at the same locality, although at different depths.

Key to the species of Anomalopidae

1a. A separate spinous dorsal fin, dorsal formula IV or V-I, 14 or 15; subocular organ rotatable or not.....3

1b. A single dorsal fin, dorsal formula II, 18–19; subocular organ cannot be rotated ventrally into a pocket, instead a black shutter lifts to cover the organ....*Photoblepharon*.....2

2a. Anteriormost lateral line pore preceded by a large white spot on dorsal corner of opercle; pelvic rays typically 7.....*Photoblepharon palpebratus*

2b. White spot on dorsal corner of opercle absent; pelvic rays 6.....*Photoblepharon steinitzi*

3a. Dorsal elements not continuous, a gap between spinous and soft-rays; lateral line nearly straight.....*Anomalops katoptron*

3b. Dorsal elements continuous, without an interspace; lateral line arched above pectoral fin, scales enlarged, transparent or reflective 4

4a. Abdominal scutes 7–9, white, enlarged and thornlike .....*Kryptophanaron alfredi*

4b. Abdominal scutes 13–18, colored like body, not enlarged and thornlike..*Kryptophanaron harveyi*

Anamalops katoptron (Bleeker, 1856)

Heterophthalmus katoptron Bleeker, 1856: 43 (type locality, Manado, Celebes).

Anomalops Graeffei Kner, 1868: 294 (type locality, Kandavu, Fiji).

Anomalops katoptron: Bleeker, 1878: 48.

Anomalops palpebratus, not of Boddaert: Günther, 1876–81: 143.

Widely distributed in the central and western Pacific oceans (Fig. 1). Weber and de Beaufort (1929: 226) listed it from Celebes, Ambon, Banda, New Guinea, New Hebrides, "Fidji-islands", Rarotonga, and the Tuamotus. Lee (1980) reported upon a 91 mm (SL) specimen (as *Anomalopsis* [sic] *katoptron*) from a tidepool in Lanyu, Taiwan. Doak (1976) reported specimens form the surface at Malaita Island, Solomons. We have found another specimen from Rarotonga, Cook Islands (BPBM 1995, 91 mm SL) collected by Alvin Seale in February/March, 1902, and Gustav Paulay (in litt. to John E. Randall, 18 Apr., 1984) described an anomalopid (probably this species) that is very abundant on Mangaia and Atiu, Cook Islands. At Atiu it is locally called "Moe ava" (sleep pass) in that "they tend to swim around in the passes at night, and serve as guides in the location of passes for the night fishermen."

Specimens from southern Japan have been identified as *A. katoptron* (Abe, 1942, 1951, 1975). Shimizu in Masuda et al. (1984: 109) lists Japanese specimens as "*A.* sp." and states that they differ from Indonesian material in having 10 rather than 9 anal soft rays. This apparently is an error in that Shimizu advises us (in litt., 16 Apr. 1986) that the eight specimens he analyzed from Banda and Philippines all have anal II, 11. However in 23 specimens from Indonesia, the Philippines and the central Pacific, we found eight with anal II, 10 and 15 with II, 11.

Since 1978, *A. katoptron* has become a common display species in public aquariums. It is commonly collected by fishermen with cast nets in Cebu, Philippines, where it inhabits shallow water during October when the water is coldest (Kent Carpenter, in litt.).

To its previously known distribution we add the following localities: AUSTRALIA, Diamond Cay (151°05′E, 17°23′S), CAS 49131 (1, 32 mm), captured by J. E. McCosker in 6 m, on 27 Nov. 1981. PAPUA NEW GUINEA, Trobriand Islands, Kiriwina Island, USNM 219451, collected by B. Collette and B. Goldman in a surge channel in 3–4 m, and in the vicinity of Madang and Motupore (Pat Colin, pers. comm.). PHILIPPINES, numerous collections made at Cebu, including CAS 55163 (5, 64–75.5 mm). GUAM, CAS 57553 (2, 232–266 mm), off Camel Rock, caught at greater than 365 m by handline by K. Nagao during Nov. 1976, and Univ. of Guam, unnumbered specimen, 242 mm, Merigo Channel (Mamoan), caught by F. Gaison bottom fishing in 110 m on 23 Mar. 1969. Kami (1971) reported on a 240 mm specimen from about 100 m off Gaum. AMERICAN SAMOA, CAS 44373 (1, 238 mm), off Tutuila Island, caught by handline by M. Makaiwi in 360 m on 3 Feb. 1978. Wass (1984) listed this specimen and notes "this species is occasionally caught by handline fishermen at depths >300 m."

Kryptophanaron harveyi
Rosenblatt et Montgomery, 1976

Kryptophaneron harveyi Rosenblatt and Montgomery, 1976: 510 (lapsus pro *Kryptophanaron*; type locality, Gulf of California, Mexico).

Known from the holotype, and another specimen captured off the outer coast of Baja California (Fig. 1), which we herein describe. A large, gravid female specimen, SIO 78–299, was caught on 3 Oct. 1978 by a hook-and-line fisherman aboard M/V Qualifier at Thetis Bank, offshore from Cape San Lazaro (24°48′N, 112°19′W). The least charted depth of Thetis Bank is ca. 35 m. The specimen has the following measurements (in mm): standard length 204; predorsal 83.4; prepelvic 83.1; preanal 150.4; body depth 92.9; caudal peduncle depth 25.7; caudal peduncle length 39.8; snout 17.7; eye 18.2; orbit 19.3; light organ length 16.0; light organ depth 6.5; upper jaw 36.5; pelvic length 41.0; pectoral length 46.0. Counts are: D IV-II, 15; A II, 9; P_1 ii, 13i; P_2 I, 6; caudal 9, 10+9, 8; branchiostegals 8; gill rakers 8–1–15; lateral line pores 38; scale rows above lateral line 10; belly scutes 17. This second specimen is almost three times larger than the 67.7 mm holotype and differs from it in the following manner: the mouth is larger and less oblique, the body is considerably deeper, the head canals are more extensively roofed by bone, and the eye is relatively much smaller. The spinous dorsal fin is aberrant in that the 2nd and 3rd spines are twisted, the 4th is a nubbin, and the bases of the first three spines are crowded such that there is a scaled interspace between the 3rd and 4th spines. Like that of the holotype, the vertebral formula of this specimen is 14+16 (the original description is in error).

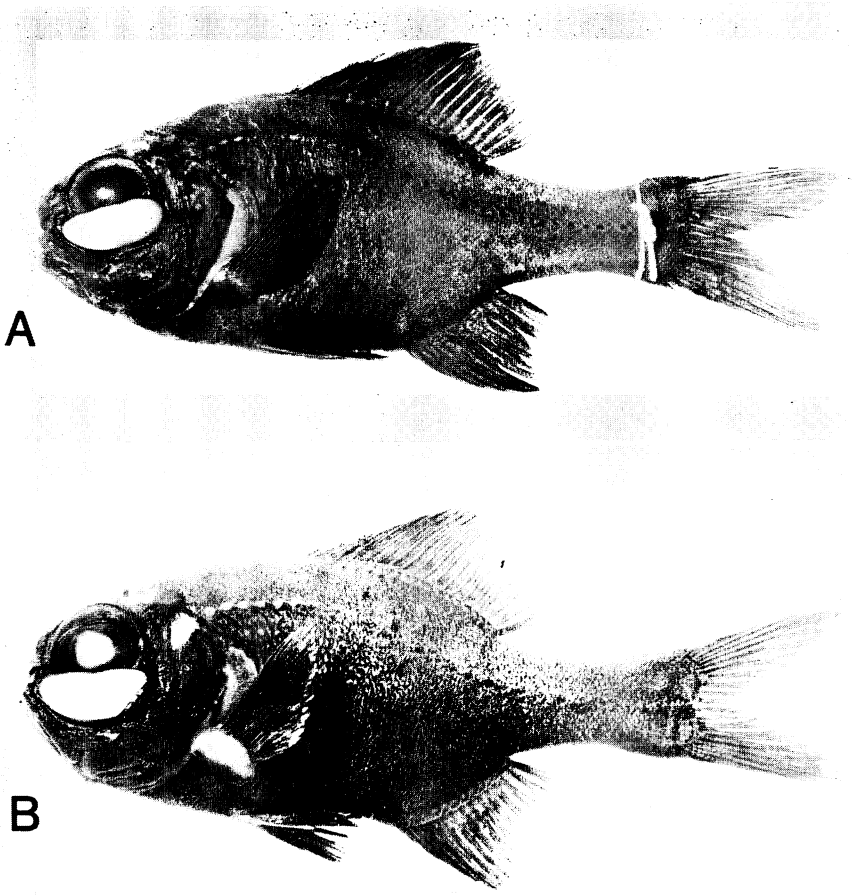

Fig. 2. Coloration of *Photoblepharon* species. In particular, note the difference in the condition of the white spot at the anterior portion of the lateral line. A, *P. steinitzi*, CAS 31480, 83 mm SL; B, *P. palpebratus*, CAS 44175, 53 mm SL.

Kryptophanaron alfredi
Silvester et Fowler, 1926

Anomalops "a new species": Dahlgren 1908: 454 (description of its light organ).
Kryptophanaron alfredi Silvester and Fowler, 1926: 246 (type locality, Jamaica).

The type and only known specimen was lost subsequent to its description. Colin et al. (1979) "rediscovered" the species and redescribed it on the basis of one specimen from western Puerto Rico caught in a fisherman's trap set at 200 m depth and six specimens from Grand Cayman collected in 30–36 m (Fig. 1). They noted several meristic discrepancies between their specimens and the holotype; it seems most likely that Silvester and Fowler were in error. McCosker (1982) reported on specimens collected from moderate depths (20–25 m) at San Salvador, Bahamas.

Additional material of this species has been collected at night near Mayaguez, Puerto Rico and is deposited at ANSP, CAS, SIO, and other museums, including CAS 45872 (2, 84–90 mm), collected by P. Colin in Feb. 1979. This species has also been observed and/or captured at Curacao (Charles Arneson, pers. comm.) and St. Croix, Virgin Islands (Edward Brothers, in litt.). The St. Croix fish were seen and captured between 25–35 m along the west wall of the Salt River Canyon.

Photoblepharon palpebratus
(Boddaert, 1781)
(Figs. 2B, 3B)

Sparus palpebratus Boddaert, 1781: 55 (type locality, Indonesia).
Photoblepharon palpebratus: Weber 1902: 108 (new genus).

Photoblepharon was little known or observed outside of Indonesia until it was found in the Red Sea. At that time, the Red Sea specimens were thought to represent a new species (Fridman, 1972), but when published, were only afforded subspecific status, as *P. palpebratus steinitzi* Abe and Haneda (1973). We consider the Red Sea and western Indian Ocean populations to be differentiated at the species level (see below).

Collections made by nocturnal scuba divers at many Pacific localities have added many additional records to the original localities of Ambon and Banda (Fig. 1). Laboute and Magnier (1983) published a photograph of *P. palpebratus* from New Caledonia and stated that it is seen at night between 5–50 m on the outer reef. Amesbury and Myers (1982: 27) report that it has been observed but not as yet captured "by divers at night at the 'Blue Hole', a large cave in the face of a steep dropoff on the leeward coast of Guam". We herein add the following new localities for this species: PHILIPPINES, as is the case of *Anomalops katoptron*, numerous specimens of this species have been collected in the vicinity of Cebu and sold to the worldwide aquarium trade. Our specimens include: Cebu, CAS 44061 (5, 68–76 mm), collected by K. Carpenter on 10 Oct. 1978, and CAS 44190 (1, 69 mm), Mindoro, off Apo Reef, collected at 13–20 m off reef face by P. Humann on 21 Mar. 1979. MARSHALL ISLANDS, Kwajalein Atoll, BPBM 29665 (1, 58 mm), Ennubuj, ocean side, collected by C. Arneson on 4 Jan. 1984 at 25 m depth, and CAS 44175 (3, 50.5–61 mm), South Pass near Kwajalein Island, collected in 15 m by D. Johnson, 23 June 1979. P. Colin (pers. comm.) has collected several individuals at Enewetak. CENTRAL CAROLINES, Oroluk Atoll, CAS 58174 (3, 66–69 mm), Oroluk Island, outer reef face, collected by J. McCosker, D. Robinson and M. Gawel at 7–10 m, at 22: 00 on 6 Feb. 1986. COOK ISLANDS, CAS 58145 (2, 67–75 mm), Rarotonga, off Avarua Pass, near inside lagoon channel, 15 m, by R. Kiwala et al. on 20 Apr. 1982. AUSTRALIA, seen but not captured by J. E. McCosker at Diamond Cay (151°05′E, 17°23′S) in 15 m, on 27 Nov. 1981. PAPUA NEW GUINEA, collected by P. Colin (pers. comm.) in the vicinity of Madang and Motupore Islands.

Photoblepharon steinitzi
Abe et Haneda, 1973
(Figs. 2A, 3A)

Photoblepharon sp. Fridman 1972: 1 (notes on the ecology of a "new species" from the Gulf of Elat).
Photoblepharon palpebratus steinitzi Abe and Haned (sic), 1973: 57 (type locality, Ras Burka, Red Sea).
Photoblepharon palpebratus, not of Boddaert: McCosker and Lagios, 1975: 1 (biology of Comoro Island specimens).
Photoblepharon palpebratus, not of Boddaert: Morin et al., 1975: 74 (behavior of Red Sea population).

We herein recognize the Red Sea and western Indian Ocean form (Fig. 1) to be distinct enough from the central and western Pacific form to warrant separation at the specific level, and therefore recognize *P. steinitzi* as a valid species. Although the differentiation of *P. p. steinitzi* was based only on the difference in number of pelvic rays, the Pacific and Indian Ocean/Red Sea populations also differ in coloration and ornamentation of the head bones (Figs. 2, 3). Although previous authors have considered the first (medial) pelvic element to be a spine, Zehren (1979: 107) noted that it is an unbranched soft-ray. The pelvic ray difference remains valid: 23 specimens of *P. steinitzi* all have 6 bilaterally and of 17 specimens from the Pacific, 13 have 7 bilaterally and four have 6 on one side and 7 on the other. No specimen of *P. palpebratus* has a bilateral pelvic count of 6.

The most important color difference is that in *P. palpebratus* there is a conspicuous white spot at the upper corner of the opercle, just in advance of the first lateral line scale. The spot is naked and covered with small papillae. In *P. steinitzi* there is a naked area at this position, but it is smaller, and either colored like the body or pale, but not conspicuously white. Although the naked area is smaller, it bears notably larger papillae. The head bones (particularly the interopercle, nasals and maxillae) are more strongly ornamented, and the dentigerous knobs of the mandible are larger in *P. steinitzi*.

Specimens of *P. steinitzi* have been collected and observed as far south as Ras Muhammed in the Red Sea, however no adequate collecting ef-

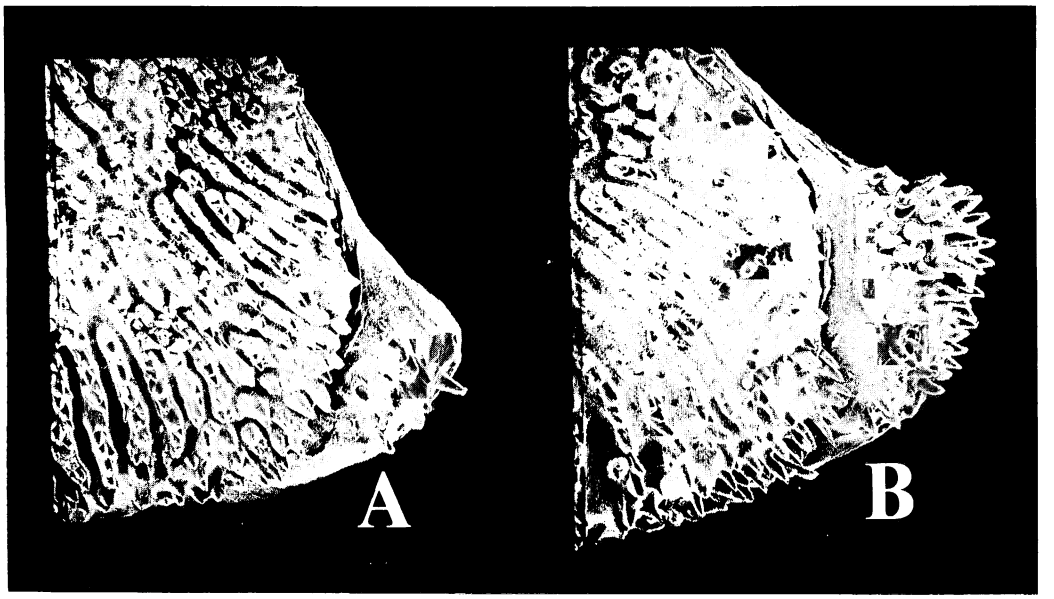

Fig. 3. Sculpturing of rear tip of maxilla and posterior of supramaxilla of *Photoblepharon* species. A, *P. steinitzi*, CAS 58177, 70 mm SL, male; B, *P. palpebratus*, CAS 41709, 70 mm SL, female.

fort has been made along the Sinai coastline. A major collecting gap exists between the east African mainland and the western Pacific. Considering the recent discoveries in the Pacific, it is quite likely that *Photoblepharon* will be found to occur across the tropical Indian Ocean.

Material examined includes, but is not limited to the following: ISRAEL, Eilat, CAS 58177 (5, 21–81 mm), captured by S. Earle on 2 Dec. 1981. EGYPT, Dahab, CAS 58175, (10, 56.5–76 mm), captured by J. McCosker and B. Metcalf, Apr. 1980. ISLE GRANDE COMORE, all captured by J. McCosker, S. McCosker and Dave Powell: CAS 31480 (1, 81.5 mm), Itsandra, 25 Oct. 1974; CAS 33885 (8, 34–84.5 mm), Hahaia, 5–80 m depth, Mar. 1975; CAS 58176 (9, 32.5–74.5 mm), Moroni, Mar. 1975.

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ヒカリキンメダイ科魚類の生物学，分類，分布について

John E. McCosker • Richard H. Rosenblatt

ヒカリキンメダイ科魚類の生物学，分布に関する新知見を報告する．本科には5有効種があり，ヒカリキンメダイ *Anomalops katoptron* と *Photoblepharon palpebratus* は太平洋中西部に広く分布し，*P. steinitzi* は紅海とコモロ諸島，*Kryptophanaron alfredi* はカリブ海，*K. harveyi* はバハ・カリフォルニアにそれぞれ見られる。*P. steinitzi* と *P. palpebratus* は色彩，頭部の形態，腹鰭条数などが異なる．*K. harveyi* の2番目に得られた個体を詳しく記載した。*Anomalops* の大型個体は深い所に，小型のものは浅い所に見られることについて考察した．本科の各種のシノニムと検索表を示した．