Taxonomy and Ecology of Mudskippers(Gobiidae: Oxudercinae) in Southern Thailand

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ชื่อวิทยานิพนธ์	อนุกรมวิธานและนิเวศวิทยาของปลาตีน (Gobiidae: Oxudercinae) ในภาคใต้ของประเทศไทย
ผู้เขียน	นาย อุดมศักดิ์ ดรุมาศ
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บทคัดย่อ

การศึกษาครั้งนี้ได้ทำการสังเกตและเก็บตัวอย่างปลาตีนในบริเวณชวากทะเลในภาคใต้ของประเทศไทยโดยเลือกพื้นที่ศึกษาทั้งหมด 22 จุด ทั้งฝั่งทะเลอันดามันและฝั่งอ่าวไทยระหว่างเดือนตุลาคม 2537 - ตุลาคม 2538 ตัวอย่างปลาที่เก็บได้จากทุกจุดนำมาทำการศึกษาทางอนุกรมวิธานและชนิดของอาหารที่ปลากิน การศึกษา food niche overlap ได้ทำการใน 4 จุด ซึ่งมีรูปแบบของการอยู่ร่วมกันของชนิดปลาตีนที่ต่างกัน การศึกษาเกี่ยวกับอนุกรมวิธานแสดงในรูปแบบอธิบายและค่าสถิติพื้นฐานได้แก่ ค่าสูงสุด, ค่าต่ำสุด, ค่าเฉลี่ย และ ค่าเบี่ยงเบนมาตรฐาน การศึกษาอาหารที่ปลาตีนแต่ละชนิดกินแสดงในรูปแบบร้อยละของความถี่ของอาหารแต่ละชนิดที่ปรากฏ และ Relative Importance Index ส่วนการศึกษา food niche overlap ได้มีการดัดแปลง Horns' index of niche overlap เพื่อให้เหมาะสมกับการศึกษา

ผลจากการศึกษา พบปลาตีน 10 ชนิด ในภาคใต้ของไทยได้แก่ *Boleophthalmus boddarti*, *Periophthalmodon schlosseri*, *Pn. septemradiatus*, *Periophthalmus argentilineatus*, *Ps. chrysospilos*, *Ps. gracilis*, *Ps.* cf. *novaeguineaensis*, *Ps. novemradiatus*, *Ps.* species A และ *Scartelaos histophorus* ในจำนวนนี้มี 3 ชนิด เป็นชนิดที่ยังไม่มีรายงานในประเทศไทยได้แก่ *Periophthalmus chrysospilos*, *Ps.* cf. *novaeguineaensis* และ *Ps.* species A

B. boddarti และ *Ps. novermradiatus* สามารถพบได้ทั่วไปในชวากทะเลในภาคใต้ของไทย ส่วน *Pn. schlosseri* พบเฉพาะฝั่งอ่าวไทย และ *Ps.* species A พบในฝั่งทะเลอันดามัน แต่ *Pn. septemradiatus*, *Ps.* cf. *novaeguineaensis* และ *Ps. gracilis* สามารถพบที่ระนองเท่านั้น

จากการศึกษาองค์ประกอบอาหารที่พบในท้องปลาตีนกินทำให้สามารถจำแนกปลาตีนออกเป็น 3 กลุ่ม คือ

1. พวกกินพืช (herbivore) ได้แก่ *B. boddarti* กิน ไดอะตอม (*Pleurosigma* และ *Gyrosigma*)ที่ปรากฏอยู่ตามพื้นเป็นหลัก

2. พวกที่กินทั้งพืชและสัตว์ (omnivore) ได้แก่ *S. histophorus* กิน ไดอะตอม เช่น *Pleurosigma* และ *Gyrosigma* ที่ปรากฏอยู่ตามพื้นและสัตว์เล็ก ๆ ที่อาศัยในพื้นโคลน เช่น โคพีพอด เป็นต้น

3. พวกที่กินสัตว์ (carnivore) ประกอบด้วยสมาชิกใน สกุล *Periophthalmus* จำนวน 6 ชนิด และสมาชิกใน สกุล *Periophthalmodon* จำนวน 2 ชนิด โดยพวกนี้จะกินอาหารได้หลายอย่างเช่น ปู แมลง และกุ้ง เป็นต้น

จากการศึกษา food niche overlap ของปลาตีนที่อยู่ร่วมกันในสถานที่เดียวกัน พบว่าระหว่าง *B. boddarti* และ *S. histophorus* มีค่าเท่ากับ 0.608 หมายความว่า อาหารที่ *B. boddarti* และ *S. histophorus* มีความแตกต่างกันในแง่ของ food niche overlap อยู่ในระดับปานกลาง นอกจากนี้อาหารหลักของ *S. histophorus* อาจเป็นสัตว์เล็ก ๆ ที่อาศัยในพื้นเลนก็ได้ แต่ระหว่างสมาชิกของกลุ่มที่กินสัตว์เป็นอาหารนั้น ค่า food niche overlap มีค่าสูงมาก เช่น ค่า food niche overlap ระหว่าง *Ps. novemradiatus* กับ *Ps. chrysospilos* = 0.843 และระหว่าง *Ps. argentilineatus* และ *Ps.* cf. *novaeguineaensis* = 0.993 ซึ่งน่ามีการแก่งแย่งอาหารกันระหว่างพวกที่กินสัตว์ด้วยกันอย่างรุนแรง แต่จากการสังเกตพฤติกรรมการกินอาหารพบว่าพวกนี้มีความพยายามที่จะเลี่ยงการแก่งแย่งอาหารกันโดยการออกหากินในสถานที่ต่างกัน หรือการออกหากินในเวลาที่ต่างกัน นอกจากนี้บางชนิดที่อยู่ด้วยกันมีความแตกต่างกันของขนาดอย่างชัดเจน เช่น *Pn. schlosseri* ซึ่งมีขนาดใหญ่กว่า *Ps. novemradiatus* ประมาณ 10 เท่า

ถึงแม้การศึกษาครั้งนี้จะสามารถอธิบายได้ว่า ปลาสามารถอยู่ด้วยกันในสถานที่เดียวกันโดยแบ่งการใช้ทรัพยากรอาหารกัน ไม่ว่าจะแบ่งโดยสถานที่หรือเวลาก็ตาม แต่ก็ยังมีปัจจัยอื่น ๆ ที่มีผลต่อกระบวนการนี้ เช่น การมีอาหารในปริมาณมาก, การมีการเปลี่ยนแปลงชนิดและปริมาณของอาหารอย่างรวดเร็ว, การมีผู้ล่าควบคุมความหนาแน่นของปลาตีนให้ต่ำกว่าค่า carrying capacity ของระบบนิเวศที่สามารถรองรับได้, ความสามารถในการเปลี่ยนชนิดของอาหาร หรือความสามารถในการปรับตัวต่อสิ่งแวดล้อมทางกายภาพ เป็นต้น

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Abstract

This study was carried out in Southern Thailand. Mudskippers were observed and collected, at twenty-two selected estuarine sites, in both the Gulf of Thailand and the Andaman Sea, from October 1994 to October 1995. Specimens were investigated for their taxonomic characteristics and their food consumption. Four particular study sites were identified and different species combinations and their food niche overlaps were documented. Taxonomic studies focused on observation of simple statistical measures of dimensions such as: maximum, minimum, mean and standard deviation. The percentage rate of occurrence and Relative Importance Index were used in the food items investigations. Horns' index of niche overlap is slightly modified in the food niche overlap study.

The results show that ten species of mudskippers (Family Gobiidae: Subfamily Oxudercinae) were found in Southern Thailand. They include *Boleophthalmus boddarti, Periophthalmodon schlosseri, Pn. septemradiatus, Periophthalmus argentilineatus, Ps. chrysospilos, Ps. gracilis, Ps.* cf. *novaeguineaensis, Ps. novemradiatus, Ps.* species A, and *Scartelaos histophorus.* Three species are new records for Thailand: *Ps. chrysospilos, Ps.* cf. *novaeguineaensis*, and *Ps.* species A. *B. boddarti* and *Ps. novemradiatus* are commonly known to occur in Thailand, while *Pn. septemradiatus, Ps.* cf. *novaeguineaensis* and *Ps. gracilis* are present only in single locations. *Pn. septemradiatus* and *Ps.* cf. *novaeguineaensis* were found only La-Un (Ranong) and *Ps. gracilis* present only Ngao (Ranong). *Pn.*

schlosseri was present only in the Gulf of Thailand, while *Ps.* species A was found in the Andaman Sea. Food items found in mudskippers' stomachs tell us that they can be divided into three groups: herbivores (only one species: *B. boddarti*, which feed only on benthic diatoms); carnivores (consisting of members of the genus *Periophthalmodon* -2 species and *Periophthalmus* -6 species. They feed on several kinds of food such as crabs, insects and shrimps); omnivores (only *S. histophorus*, which feeds on benthic flora and several kinds of benthic meiofauna). As herbivores, *B. boddarti* do not have problems of food niche overlap with other carnivores, but do have overlap with omnivores (such as *S. histophorus*) to a moderate extent (0.608). However, they are able to coexist, perhaps because the main foods of *S. histophorus* are benthic meiofauna. Food niche overlap among carnivorous species, particularly in some combinations, is high (For example; *Ps. chrysospilos* VS. *Ps. novemradiatus* at Laem Hin, Phuket is 0.843 or *Ps. argentilineatus* VS. *Ps.* cf. *novaeguineaensis* is 0.993). However, according to the findings of this study, they try to avoid food competition by adopting several strategies, such as using different feeding times and different feeding grounds. Some coexisting species are different in size; *Pn. schlosseri*, for example, is about ten times larger than *Ps. novemradiatus*. They may not be in competition, because of their different sizes.

Nevertheless, the study is inconclusive in terms of describing which are the key factors controlling mudskipper species coexistence. There are a number of possibilities: that food sources are sufficiently abundant; that food supplies fluctuate but mudskippers have the ability to switch prey (at different life stages and/or between different species); that they have the other abilities which enable them to cope with changes in their physical environment, other competitors, parasites, predators and other interactions.

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Udomsak Darumas

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Chapter 1

Introduction

In general, ecologists do not expect to find closely related species which use similar resources coexisting together. Competition for food, space for breeding, shelter, etc. is thought to eventually force species to adapt themselves to use different resources, or to become extinct.

Many studies, however, have shown that competition does not necessarily exist between two coexisting species that use similar resources. For example, it is not fully understood why and how five common species of social wasps in England, of the genus *Vaspular*, which have similar body sizes and must compete with each other directly for food in the same area, successfully coexist (Varley and Gradwell, 1973, quoted in Birch, 1979). A study in eastern North America, was unable to find evidence that two species of salamanders (*Pletbodon boffmani* and *P. punctulatus*) affected each other in any way, in spite of the fact that they lived in the same places at the same time. *P. boffmani* has a contiguous distribution with *P. punctulatus.* The young have very similar diets; the adults differed in size and there were some differences in the food they consumed, but no evidence was found that they ever ran short of their common food or that their nesting sites were limited (Fraser, 1976a; 1976b, quoted in Birch, 1979).

A study in Queensland showed that at least five species of predatory mudskippers can live in the same area by successfully partitioning their habitat and resources (Whitten *et al.,* 1987). Many studies have documented that there should be differences in the niches that coexisting species occupy (such as Ross, 1977; Wissinger, 1992). Coexisting species might, for example, occupy places with differing physical gradients, chemical gradients and particularly, biological gradients which are affected by many factors such as: predation, competition, and the availability of different natural resources etc.

If animals which have similar requirements coexist in the same area they may compete for limited resources. However, many studies could not find any evidence of competition among such. The question is: how do the species coexist successfully. The possible explanations for this question vary according to the nature of the interactions between the species involved and the following studies showed:

The study of resource partitioning by the sympatric gray fox (*Dusicyon griseus*) and culpeo fox (*D. culpaeus*) shows that the seasonal and annual home ranges of culpeo foxes were larger than those of gray foxes. But their home range never overlap with each other. The gray foxes inhabit in upland shrub habitat, while the cupeo foxes occupy the thicket of tree and in the area of high cover density (Johnson and Franklin, 1994).

In leeches and triclad communities on stone shores, the coexistence of species was facilitated by the presence of food refuges. Leeches are more successful than triclads at capturing live prey, whereas both groups feed on damaged prey, comprised of incapacitated, live or dead animals that have leaked body fluids. It is concluded that the coexistence of leeches and triclad species are assisted by the partitioning of food on a damaged or live basis (Seaby *et al.,* 1995).

A study of goatfish (Mullidae) along the Mediterranean coast of Israel documented that prey size is not an important factor in niche separation among the coexisting species, but the difference between the spawning season of the colonizing versus indigenous species. The consequent timing of benthic setting may contribute to niche separation (Golani, 1994).

The level of resource partitioning of Africa bovidae (*Bovidae*) was based on diet, primary food preference, habitat preference, and feeding height preference (Spencer, 1995).

In littoral zones of Lake Takvatn in northern Norway, charr and stickleback had different feeding habits. Stickleback ate several small benthic prey items that were never eaten by charr (Joergensen and Klemetsen, 1995).

In a mangrove bird community in peninsular Malaysia, the obligate foliage-feeding insectivores and facultative nectarivores partitioned their resources by using different feeding techniques (Noske, 1995).

The study of food niche overlap and ecological separation in a multi-species community of shrew in the Siberian taiga shows that all species of shrew took a wide range of invertebrate prey, and overlap in the members of shared prey taxa was high, but differences in dietary composition of certain taxa reduced overlap between most species (Churchfield and Sheftal, 1994).

Another community which harbours many species of animals is the mangrove community, which is affected by many physical factors, particularly the salinity changes. The salinity gradient is caused by the dilution of seawater by freshwater. Changes in freshwater input can strongly influence the downstream-upstream distribution of salt (Levinton, 1982). The nutrients in mangrove ecosystems originate from three sources: river inputs, marine inputs and bottom sediments. The particulate matter may be deposited on the bottom of the estuary, becoming a food source for benthic organisms living there and entering the food web. A flow of deep sea water towards the land brings dissolved nutrients into the estuary which can be utilized by phytoplankton. Phytoplankton become less abundant with distance from the estuary, and primary productivity can be 20 times as great in an estuary as it is in the open sea (Doty *et al.,* 1963, quoted in Whitten, 1987).

Although salinity changes limit the species richness in mangrove ecosystems, species diversity in this ecosystem is high. For example, there are 92 species of macrofauna at mid intertidal zones in mangrove communities in Thailand (Frith, 1976; Frith, 1977, quoted in Robertson and

Alongi, 1992). Another role of mangrove communities, is to provide a nursery ground for marine animals, many of which are economically valuable.

So why do mangrove communities carry such a high diversity of species? There are at least two explanations: first, there is, in mangrove communities, the high primary productivity and a diversity of primary production which can support many species: second, the physical changes, particularly, the salinities depend on tides, and seasonal changes allow animals to occupy different niches (places and times) depending on the adaptability of each species. However, many species which are not able to adapt themselves to fit with environmental fluctuations, can move to more suitable niches, (e.g. mangrove snails, grapsid crabs and mudskippers.)

Mudskippers live out of water most of the time. They have to be able to adapt to significant changes in their physical environment as well as salinity changes. However, we do not know what forces them to stay out of water. In order to live out of water, they have to breathe air, prevent skin desiccation, feed on land, escape from predators on land as well as make other ecological adaptations.

At present, knowledge about the biology and ecology of mudskippers is lacking, particularly in terms of their ecological role in mangrove communities as well as their importance in the mangrove food chain(Whitten, 1987a,b; MacNae, 1968). Examples, of important questions are: What sort of consumers are they? Are species of mudskippers present at different trophic levels in the mangrove food chain? This implies that mudskippers are one of the important components of nutrient cycles and energy flow in the mangrove food chain. What are their positions in the mangrove food web? The population density of mudskippers is an important influence over population densities of other species which have contact with mudskippers in the food web (Whitten,1987a).

If there are several species of mudskippers coexisting in any habitat, how do they coexist?, what are the factors forcing them to coexist (such as predation, parasitism, competition, resource patitioning)?

Mudskippers have been used by researchers to investigate levels of heavy metal in their tissue (Uchida *et al.*,, 1971; Patel *et al.*,, 1985, quoted in Clayton, 1993). Mudskippers (*B. boddarti*) have been cultured in Taiwan since 1984, but the hatchery technology has not yet been fully developed. Mudskipper fingerlings have to be taken for culture from the wild (Lo-Chai, 1990). Artificial culture is not yet feasible because there is, as yet, insufficient understanding of their life history, biology and ecology (Lo-chai,1990).

The objectives:

1. To identify the number of species, species composition and taxonomic status of mudskippers in southern Thailand.
2. To obtain basic ecological information about the habitats in which mudskippers live.
3. To study the feeding habits and the types of food which each species consumes.
4. To investigate food consumption and aspects of coexistence of mudskipper species living in the same area.

Literature Review

Mudskippers have been effectively categorized into different genera. Species of *Periophthalmus* were described by ecological differences and sought for recognized morphological differences between members of this genus (Harm, 1929; Eggert, 1929a; 1935, quoted in MacNae, 1968). One researcher stated that *P. argentilineatus* C.andV., *P. vulgaris* Eggert and *P. koelreuteri* Pallas are all, in fact, one species, which he identified as *P. kalolo*

Lesson (Whitley, 1953, quoted in MacNae, 1968). Mudskippers were previously placed in the order Perciformes, suborder Gobioidei, family Periophthalmidae (Faculty of Fisheries, Kasetsart University, 1990). Some of the species names of mudskippers are confusing and some species names are no longer valid such as *Periophthalmus vulgaris and P. koelreuteri* (Clayton, 1993). Murdy (1989) revised the taxonomy of mudskippers and their related species and placed mudskippers into the sub-family Oxudercinae, family Gobiidae.

Mudskippers live on mud flats, generally near or in mangrove areas. They are widely distributed in tropical and sub-tropical areas (Murdy, 1989). On eastern African shores, mudskippers occur within the mangrove from a level close to the seaward fringe, upwards almost to the level reached by high water during ordinary spring tides (MacNae, 1968). They are sometimes found climbing up the roots and trunks of the mangroves (Frank, 1971).

Some information on mudskippers has been documented for a considerable time. For example, it has been shown that the brain of carnivorous *Periophthalmus* is larger than herbivorous *Boleophthalmus* (Datta and Das, 1980, quoted in Clayton, 1993). Mudskippers do not have lateral lines, so they are limited to epidermal organs (neuromasts) which are the chemoreceptors (Afzelius, 1956, quoted in Clayton, 1993). Their eyes are dorsally protruded and unique in a number of ways (Graham, 1971, quoted in Clayton, 1993; Frank, 1971), and move independently of each other, retracted into the head where they are covered by ventrally placed lid-like skin flaps (Karsten, 1923; Munk, 1970, quoted in Clayton, 1993).

The movement of mudskippers on land is facilitated by the appendicular skeleton and muscular adaptations. A form of adductor superficialis muscle is adapted for terrestrial locomotion (Frank, 1971). They lever themselves forward on their pectoral fins, which are synchronized with each other, leaving characteristic tracks, as found in *Periophthalmus*, *Periopthtalmodon* and *Boleophthalmus*, but not *Scartelaos* (Eggert, 1828b;

Harris, 1961; Murdy 1989, quoted in Clayton, 1993). De and Nandi (1984) suggested that *B. boddarti*, besides swimming, uses four different modes of locomotion (crutching, skipping, skimming and climbing). Locomotion by crutching is mainly for the purpose of acquiring food, while skipping and skimming are used to escape predators. Climbing is used in mud areas. They also skip over the mud by flicking their tails, and climb on vegetation to attain higher levels in the mangroves in which to rest. Mudskippers move in a variety of ways. The details of their of axial skeleton, spinous dorsal fin pterigiophore formula are important in terms of their taxonomy (Birdsong *et al.* 1988, quoted in Clayton, 1993). Other morphologies such as the head and the position of the mouth relate to their method of foraging (Mehta, 1990, quoted in Clayton, 1993). Their jaw dentition has been used to group carnivore species and herbivore species. The carnivore, *P. barbarus* [as *P. koelreuteri*] has canine-like teeth but the herbivore, *Boleophthalmus,* does not (Sponder and Lauder, 1981, quoted in Clayton, 1993).

Mudskippers, *Boleophthalmus, Periophthalmus* and *Periophthalmodon* in west Bengal, spawn between May or July and September or October during monsoon periods when the pH level and salinity are reduced, and the standing crop of plankton is increased (Sircar and Har 1975, quoted in Clayton, 1993). Eggs of Periophthalmids require longer periods to hatch than do Boloeophthalmids (Clayton, 1993). However, the degree of hatching success is dependent on many factors such as temperature and salinity. The optimum temperature and salinity for hatching were 28 °C and 15-25 ppt respectively (Zhang *et al.,* 1987,1989, quoted in Clayton, 1993)

Because mudskippers live in a wide variety of physical conditions, their adaptability or tolerance range to changing environmental conditions is of particular interest. Mudskippers are generally regarded as euryhaline fish. They can live in a range of 0-100% sea water (see Table 2, p 524 in Clayton, 1993) by changing the water content in their muscles to stabilize the ion concentration in their blood. These mechanisms are useful for staying in the air as well (Gordon *et al.,* 1965, quoted in Clayton, 1993). In the air, mudskippers were observed to always keep their tails in water. It is believed that they use caudal respiration (Higson,1889, quoted in Frank, 1971; Clayton, 1993). The other organs such as skin buccle and pharyngeal cavities and opercular spaces were considered as accessory respiratory organs. Under water, mudskippers breathe just like other fish, while in air they store oxygen by holding water and air in their gill chambers. Oxygen is supplemented by gas exchange through their skin and fins. Another problem in staying out of the water is the changes in environmental temperature. Mudskippers use body color change, evaporative cooling and other thermo-regulatory behaviors, keeping body temperature in line with environmental temperature (Tytler and Vaughan, 1983, quoted in Clayton, 1993). Mudskippers are able to inhabit several kinds of substratum such as mudflats, seagrass surfaces, sandy-rock shores. Their location depends on the habitat preferences of each species and other dependent and independent factors. Their distribution is based on each species ability to live out of water (Clayton, 1993). *Scartelaos* is considered more aquatic than *Boleophthalmus* and lives in very soft mudflats. *Periophthalmus* is the most terrestrial of all mudskippers. Mudskippers are eaten by several predators such as sea snakes, cat fish, stone fish, water birds and reptiles (Clayton, 1993).

Members of the mudskipper family can be carnivores, herbivores or omnivores. The foraging behavior of carnivores is as “sit and wait predators,” while herbivores graze on benthic flora on mud surfaces and omnivores use barbels to detect their small prey in very soft mud, and also sometimes graze on benthic diatoms. However, there are great variations in mudskippers' diets. Mudskippers feed on a wide variety of live foods (Frank, 1971). But the first food of mudskipper larvae is particulate organic detritus of benthic diatoms decomposed by natural means (Qiyong and Zhang, 1988). Although they look very similar, the different species of adult mudskippers have very different diets; *B. boddarti* takes mud into its mouth, retaining algal material, and blows out the rest. Other species are omnivorous, eating small crustaceans as well as some plant material; and P. *koelreuteri* is a voracious carnivore feeding on crabs, insects, snails, and even other mudskippers. *Perioptthalmodon schlosseri* goes into the mangrove, following the advance of the tide, for prey.

Their rhythmic behaviors are affected by both circadian and tidal changes. The rhythmic behavior of *B. pectinirortris* is high at low tide on the shore. When the tide is rising, *P. kalolo* skitters over the surface to the water from refuge to refuge, but rarely climb trees in the fashion of *P. chrysospilos*. However, they may perch on a branch just at, or slightly above, the water level, or embrace a twig or root using their pectoral fins as "arms." *P. chrysospilos* does not stray far from its "home" in the seaward A*vicennia* and S*onneratia* fringes. As the tide rises, the fish climb into trees and cling to branches using the sucker formed by the fused pelvis fins. (MacNae, 1968). Some species of genus *Periophthalmus* (*Periophthalmus argetilineatus* and *P. chrysospilos*) are active only in daytime (Stebbins and Kalk, 1961; Magnus, 1972 and Al Napi, 1977, quoted in Clayton, 1993). Most of them *(P. argentilineatus, P. waltoni, Boleophthalmus sp.* and *Pn. schlosseri*) construct their own burrows and have territorial areas. Territory sizes depend on fish density, as in *B. boddarti* (Clayton, 1988). Territory is marked by deposited mud balls around the burrow. However, some of them are non-territorial, errant fish. Fish defend territory by expanding their dorsal fins to threaten their opponents. There is more complex behavior in the courtship display by males, lapping into the air with all fins fully spread at the approach of a female. They give a series of substratum bound displays (Clayton, 1993).

When under attack by predators, fish may escape down the nearest burrow, although the burrow is not truly occupied. The burrows differ in shape and structure, depending on the species. Fish use burrows for escaping from pecivorous predators at high tide (Milward, 1974, quoted in Clayton, 1993).

In Thailand, there have been a few reports about species of mudskippers. For example, three species of mudskippers were found on a mangrove shore in Phuket Island: *B. boddarti*, *P. vulgaris*, *S. viridis* (Frith *et al.,*, 1976). The same three species of mudskippers were found on Ko Maphrao, Phuket as well (Tantichodok, 1981). Two species of mudskippers were found at Ko Yao Yai, Phuket: *P. koelreuteri*, and *S. viridis* (Nateewathana and Tantichodok, 1984). Five species of mudskippers were previously included in the Fish Identification Handbook (Faculty of Fisheries, Kasetsart University, 1985*): Periophthalmus koelreutero* or *P. barbarus, Boleophthalmus boddarti, Scartelaos viridis, Perioptthalmodon schlosseri*, and *Pn. tredecemradiatus.* In Thailand there are 4 genera of mudskippers present*: Boleophthalmus, Periopthalmus, Periopthalmodon* and *Scartelaos* (Murdy, 1989). A study team looking at the ecology of Pattani Bay reported that at least 4 species of mudskippers are found in Pattani province alone*: B. boddarti, Pn. schlosseri, P. novemradiatus, P. argentilineatus* (Swennen, unpublished report). However, in general, there is a lack of biological and ecological information about mudskippers in Thailand.

Chapter 2

Materials and Methods

1. Study sites.

Eleven provinces in southern Thailand were used as locations for this study. They included the following: Andaman sea shore:Ranong, Phangnga, Phuket, Krabi, Trang and Satun. Gulf of Thailand:Chumporn, Surat-Thani, Nakorn Si Thammarat, Songkhla, and Pattani.

Yala and Phathalung provinces are not included in the list since there are neither mangrove nor salt mudflats there. In Narathiwat Province mudskippers were not found at the chosen sites, though there are mangrove plants present in this area. Mudskippers, it seems, cannot adapt to the sandy substrates which exist here.

Study sites were examined using 1:50,000 maps of southern Thailand. Two stations, which presented either mangrove or mudflat areas on the maps, were chosen as study sites in each of 11 provinces. Field surveys and local information were used to identify the study sites.

The study sites are indicated by the numbers given in brackets: (also in Fig. 1)

Province	**Study site**
Chumphorn	Ao Pak Hat (1)
	Ao Kho (2)
Surat-Thani	Khlong Changoe (3)
	Klong Yai Phum Riang (4)
Nakhon Si Thammarat	Ban Pak Maying (5)
	Ban Pak Num (6)
Songkhla	Ko Yo (7)
	Khlong Na Thap (8)

Pattani	Ban Ru Sa Mi Lae (9)
	Ban Tanyong Pao (10)
Ranong	Khlong La-Un (11)
	Khlong Ngao (12)
Phangnga	Khlong Ko Pan Yi (13)
	Ban Khok Khrai (14)
Phuket	Ban Laem Hin (15)
	Ao Nam Bo (16)
Krabi	Pak Nam Krabi (17)
	Bam Khuan to (18)
Trang	Khlong Meng (19)
	Ko Laen (20)
Satun	Ban Tam Ma Lang (21)
	Pak Ao Langu (22)

Visits were made to cover the range of mangrove areas; at least one visit per area. Specimens were collected at low and high tides.

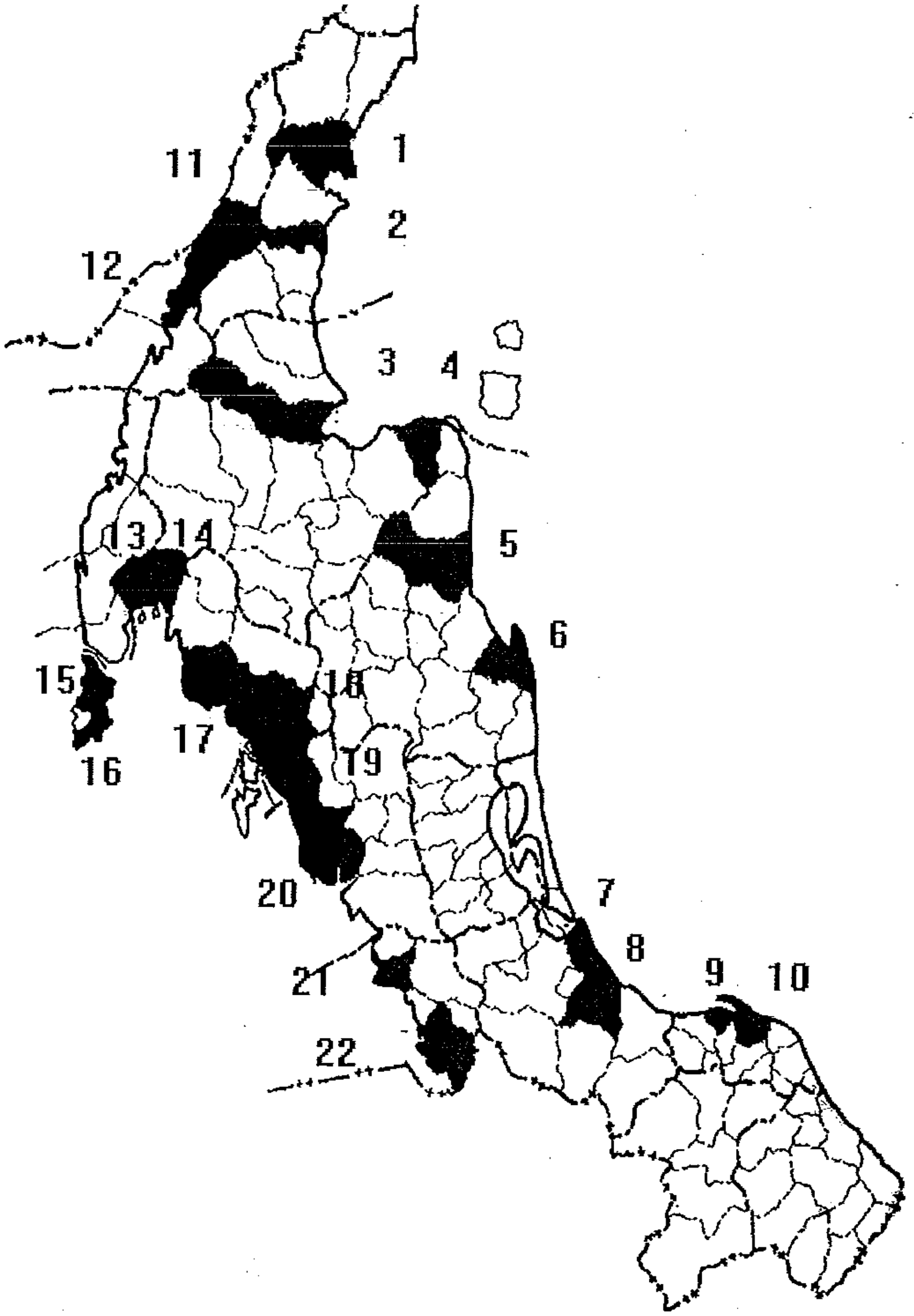

Fig1. List of the study sites with station numbers detailed (not to scale).

2. Surveying and collecting mudskippers

Surveying and collecting mudskippers were carried out during January through July in 1995. Each selected location was surveyed, either from a small boat or on foot. The range of distances was 300-2000 meters depending on the shore topography. As many fish as possible were caught. Because different kinds of mudskippers have different ecological niches, four different methods were used to catch them. The following methods were used:

2.1 Cast net

A nylon cast net, 3.5 m high and of 2.5 cm mesh size was used during low and high tides when mudskippers were present in groups or strayed from their burrows into exposed habitats such as mudflats or river banks. This method is efficient for catching *B. boddarti, Pn. schlosseri, Ps. chrysospilos* and, sometimes *S. histophorus*, also.

2.2 Barrier net

A barrier net of dimensions 1.5 meters high, 3 meters wide and of 2.5 c.m. mesh size was used to obstruct mudskippers in their habitat. This method is efficient for areas which are covered with roots and for rough habitats or even open mudflats. Mudskippers were chased into the net and caught.

2.3 Digging mudskippers' burrows using a tool.

A short handle spade is the most efficient tool for digging burrows, particularly *Pn. schlosseri's* burrow which is sometimes 2 meters deep in very soft mud. This can also be used for some species of the genus *Periophthalmus.*

2.4 Digging mudskippers' burrows by hand.

The success of this method depends on the skill of catcher as it is not easy to follow a burrow track in soft mud. Moreover, some species use emergency openings to their burrows. At least two species of mudskippers: *B. boddarti* and *S. histophorus* build their burrows with many tracks and emergency openings, which are covered by a thin muddy layer. The emergency opening is easily penetrated.

3. Taxonomic investigation

Classification was mainly based on "A Taxonomic Revision and Cladistic Analysis of the Oxudercine Gobies (Gobiidae: *Oxudercinae*)" by Murdy, (1989). The characteristics observed were as follows:

Measurements

Standard length
Body depth
Head length
Head depthTransverse scales
Head width Predorsal scales
Height of pectoral fin base
Length of first dorsal fin base
Length of second dorsal fin base
Length of anal fin base
Caudal fin length
Pectoral fin length
Pelvic fin length
Caudal peduncle depth

Counts

Pectoral fin rays (left side)
Pectoral fin rays (right side)
Longitudinal scales
Spinous dorsal fin
Total rays of second dorsal fin
Total anal fin elements

3.1 Measurements.

All measurements are straight-line distances made with vernier calipers. Methods of measurement used were as follows: (also in Fig. 2)

standard length = the distance in straight line from the anterior-most part of the snout to the caudal base

body depth = vertical distance from anal spine base to second dorsal fin base head length = distance from anterior tip of upper lip to dorso-posterior attachment of opercular membrane

head depth = vertical head depth at posterior margin of preoperculae

head width = distance between posterior margins of preoperculae

height of pectoral fin base = vertical distance between dorsal and ventral insertions of pectoral fin

length of D_1 base = distance from anterior margin to posterior margin of first dorsal fin base

length of D_2 base = distance from anterior margin to posterior margin of second dorsal fin base

length of anal fin base = distance form anterior margin to posterior margin of anal fin base

caudal fin length = distance from posterior tip of caudal peduncle to posterior tip to the longest caudal fin ray

pectoral fin length = distance from dorsal insertion of pectoral fin to tip of longest fin ray

pelvic fin length = distance from lower origin of pelvic fin to tip of pelvic fin ray

caudal peduncle depth = vertical distance from depth of caudal peduncle dorsal margin at first ray of caudal fin origin to ventral margin at first ray of caudal fin origin.

All measurements were taken to the nearest 0.1 mm.

3.2 Counts.

The first element of the anal and second dorsal fins may be a soft spine or a segmented ray. Counts of anal and second dorsal fins do not differentiate between spines and rays. The last two rays of each of the fins are very close together, share the ultimate pterygiophore and, as in common practice, were counted as a single element. Springer(1978, 1983) appears to be the most recent researcher who counted the last two rays separately (Murdy, 1989). Pectoral fin rays were counted on both the right and left sides of the body and were tabulated as separate counts. The count of the longitudinal series was begun at the dorso-posterior attachment of the opercular membrane, continued on a postero-ventral diagonal to the tip of the pectoral fin, and then in a straight line along the mid-line of the body to the posterior edge of the hypural plate. Transverse scale counts were taken from the second dorsal fin origin ventro-posteriorly to the anal fin base. Predorsal scales are those that extend from just anterior of the first dorsal spine to just posterior of the interorbital region. These were counted in a straight line.

3.3 Statistical procedures.

The value of measurements and counts of each species was calculated using Microsoft Excel (Version 5) to express in simple statistical modes the mean, standard deviation, maximum and minimum values. Each measurement was expressed as a percentage of standard length.

3.4 Photographs and Sketches.

The most complete specimen of each species was photographed and sketched in order to indicate the general characteristics and colors of fresh and preserved specimens. Specimens of each species were recorded under three categories: distribution, diagnosis, coloration.

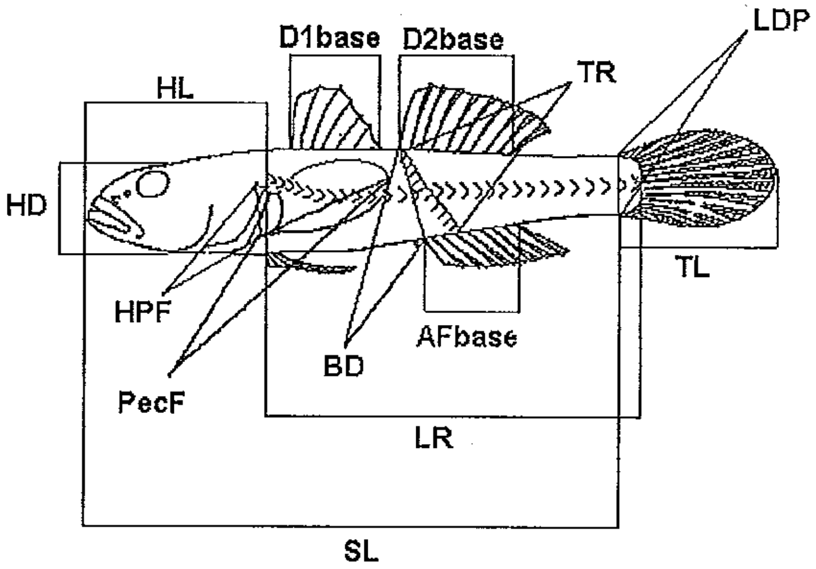

Fig. 2 Measurements and counts of mudskippers.

3.5 Taxonomic key construction

The external characteristics which are used to classify mudskippers from the generic level to the species level are as follows:

3.5.1 Barbels on underside of head

3.5.2 Number of rows of teeth in the upper jaw

3.5.3 Teeth arrangement in the lower jaw

3.5.4 Pelvic fins' shape

3.5.5 Frenum on pelvic fins

3.5.6 Characteristics of first dorsal fin and second dorsal fin

Any similar characteristics were combined in order to construct a key for the classification of mudskippers.

4. Stomach contents analysis.

All specimens were immediately injected with 10% formalin into the stomachs to preserve the gut contents. The sample were then in the 10 %

formalin solution for preservation. In the laboratory, the stomach contents of *Periophthalmus* and *Periophthalmodon*, which are carnivorous species, were washed with fresh water. The contents of each stomach were then submerged in fresh water in a petri dish and examined under a stereo-microscope. Whole and fragmented animals were sorted taxonomically and identified to the lowest taxonomic level possible. The individuals of each identified taxon were counted and, when fragments were found, the number of individuals was taken as the smallest possible number from which the fragments could have originated. The sorted stomach contents were preserved in formalin in labeled plastic bottles, mixed in the same way as stated above.

Sediment, detritus, and unidentified fragments were combined and classified as 'remaining stomach contents'. After the analysis was completed, the sorted stomach contents were dried on aluminum foil for 48 hours, at 60^0 C in an incubator, and were then weighed to the nearest mg. An investigation of food items, however, in *B. boddarti* and *S. histophorus* could not be carried out as described above, because it was not possible to weigh benthic diatoms which were the main elements of their diets. The procedure was applied from McComish(1966) and Starostka and Applegate(1970) (quoted in Hyslop, 1980). The quantities of stomach contents were estimated using an area of coverage method. The procedures were as follows: the stomach contents of each fish was washed with fresh water, diluted and mixed well. A 1 ml. sample was dropped onto a sedgwick-rafter slide, and viewed using a 10X objective compound microscope. Randomly selected individuals in 25 grids from a total of 1000 grids were counted. The contents of all diatoms present were counted in the grid area (also including those on bordering grid lines). Individuals were classified to the lowest taxonomic level under a 40X objective microscope. About 50 individuals of each diatom species were measured using a scaled eyepiece for width and length under a

10X and 40X objective microscope depending on the size of the diatom species.

Calibration of the scaled eyepiece was achieved by setting a zero mark on both scaled eyepieces and on a 0.01 mm. micrometer, and then counting marks on the micrometer from zero to the end point of the eye piece. These procedures were carried out for both 10X and 40X objectives.

4.1 Calculations

Frequencies, average numbers and average weights per fish of each food item were calculated from the data obtained. A relative importance index (RI) (known as George and Hadley's index) for the food items of each fish species was calculated using the following formula:

$$\text{Relative importance index} = 100AI / \sum_{i=1}^{N} AI \qquad (1)$$

where AI is the absolute importance index

AI = % frequency occurrence +%total number + %total weight (2)

$\sum \mathrm{AI}$ = total absolute importance index

Calculation for Relative importance index of *B. boddarti* and *S. histophorus* used the following formula:

$$\text{Calibration value (CV)} = (\sum_{i=1}^{n} \mathrm{mi}) / \mathrm{n} \qquad (3)$$

where m_i is the measurement of a scaled eyepiece using a micrometer and n is the number of measurement occasions.

$$\text{Area of coverage by species} = \sum_{i=1}^{n} [(\mathrm{WiLiCV}^2)] / \mathrm{n} \qquad (4)$$

where W_i is the value of width in the scaled eyepiece, L_i is the value of length in the scaled eyepiece, and CV is the calibration value. In formula (4) the total weight of each food species was tend expressed as a percentage of the total value of all the food species calculated in (2) and (1) respectively.

5. Ecological investigation

There are at least four combinations of coexisting mudskippers of three, or more than three, species living in the same area that have been observed during the course of this study (see below the species coexistance combinations). Sometimes, only two coexisting species were found at one place, but these patterns were also displayed in the major four combinations.

At specific study sites the followings were studied and observed.

5.1 Behavioral investigations

Feeding and other behaviors of the selected species were continuously observed, for 5 minutes in every 30 minutes, in specific habitats for three tidal cycles. It was very difficult to follow one individual's behavior, so that the first found fish was observed during the observation period. The results were recorded using a descriptive mode. The feeding habits and behavior of *Pn. septemradiatus*, was not observed because this species is very rare, and it is very difficult to differentiate it in the field from *Ps. argentilineatus*.

5.2 Food niche overlap investigations

At each location, as many mudskippers as possible were collected. This process was carried out continuously, during every low and high tide period, for three cycles. The fresh specimens were injected with a 10% formalin solution into the abdominal cavity, then preserved in the same solution. Every specimen caught was recorded in terms of standard length (mm), habitat and time collected. Stomach contents analysis was carried out as follows: each gut was rated for fullness (0.5: 0 is empty; 5 is full). Food items were classified to the lowest taxonomic level possible, then each sort of food item was rated as a proportion (percentage) of all the food present.

A list of the species coexistence combinations and study sites were as follows:

Study site	**Species combination**
Pattani Bay	*B. boddarti*
	Pn. schloserri
	Ps. novemradiatus
Laem-Hin, Phuket	*S. histophorus*
	B. boddarti
	Ps. chrysospilos
	Ps. novemradiatus
La-Un, Ranong	*B. boddarti*
	Ps. species A
	Ps. novemradiatus
	Ps. cf. *novaeguineaensis*
	Ps. argentilineatus
	Pn. septemradiatus
Ngao, Ranong	*B. boddarti*
	Ps. species A
	Ps. novemradiatus
	Ps. gracilis

5.2.1 Calculation

The food niche overlap of coexisting species at each location were calculated using Horn's Index of Overlap (1966). The formula is as follows:

$$R_o = (P_{ij} + P_{ik}) \log(P_{ij} + P_{ik}) - P_{ij} \log P_{ij} - P_{ik} \log P_{ik}] / 2 \log 2$$

where R_o = Horns' Index of Niche Overlap for species *j* and *k*

p_{ij} = Proportion resource *i* of the total resources utilized by species *j*

p_{ik} = Proportion resource *i* of the total resources utilized by species *k*

Chapter 3

Results

1. Taxonomic studies and distributions

Mudskippers were collected from October 1994 to October 1995 from each study area using the methods described above. The species of mudskippers found in Southern Thailand belong to four genera. *Boleophthalmus,* which has only a single species; *Boleophthalmus boddarti.* Six species are contained in the genus *Periophthalmus: Periophthalmus argentilineatus, Ps. chrysospilos*, *Ps. gracilis*, *Ps.* cf. *novaeguineaensis*, *Ps. novemradiatus* and *Ps.* sepcies A; *Periophthalmodon* consists of *Pn. schlosseri* and *Pn. septemradiatus*: the last genus is *Scartelaos* consisting of a single species: *S. histophorus.* All of them (except *Ps.* species A) have been described by Murdy who has produced a revised taxonomy and cladistic analysis of the oxudercinid gobies (Gobiidae: Oxudercinae) in 1988.

Previous studies, carried out in Thailand, have shown that only five species of mudskipper are present in the country: *Periophthalmus koelreuteri* or *P. barbarus, Boleophthalmus boddarti, Scartelaos viridis, Pn. schlosseri* and *Pn. tredecemradiatus* (Faculty of Fisheries, Kasetsart University, 1985). Some of them, however, have altered names: *Periophthalmus koelreuteri* or *P. barbarus* is *Ps. argentilineatus, Pn. tredecemradiatus* is *Pn. septemradiatus* and *Scartelaos viridis* is *S. histophorus* (Murdy, 1989).

This study has found four new records to Thailand: *Ps. chrysospilos, Ps.* cf. *novaeguineaensis, Ps.* species A. and *Ps. novemradiatus.* The *Ps.* species A may be a new species, because its characteristics do not fit to any of the available identification keys (Robinson, 1903; Tomiyama, 1936; Smith, 1959 and Murdy 1989).

The taxonomic status of *Ps.* species A is being investigated.

They are distributed along river edges, mangrove fringes, swamps and exposed mudflats in estuaries in southern Thailand (Fig. 2). Five species are present in the Gulf of Thailand: *B. boddarti, Ps. chrysospilos, Ps. novemradiatus, Pn. schlosseri* and *S. histophorus*. Eight species occur in the Andaman Sea: *B. boddarti, Ps. argentilineatus, Ps. chrysospilos, Ps. gracilis, Ps.* cf. *novaeguineaensis, Ps. novemradiatus, Ps.* species A. and *Pn. septemradiatus*. Some of them are common: *B. boddarti* and *Ps. novemradiatus;* while those found in only one location are: *Ps. argentilineatus, Ps. gracilis, Ps.* cf. *novaeguineaensis and Pn. septemradiatus* found only in Ranong. Members of the genus *Periophthalmodon* are found on both sides of Thailand; *Pn. schlosseri* occurs only in the Gulf of Thailand but *Pn. septemradiatus* is found in the Andaman Sea. *S. histophorus* is present on both sides of southern Thailand and each locality is distant from the other (Phuket in the Andaman Sea and Chumporn in the Gulf of Thailand).

Characteristics of each species are used to construct the simple identification key from genus level to species level, and to identify the taxonomic status of each species as described below:

1.1 Taxonomic Key of Oxudercinae (Mudskippers only)

1.1.1 Key to Genera of Oxudercinae

1a. Barbels present on underside of head..*Scartelaos*

1b. No barbels on underside of head..2

2a. Two rows of teeth on upper jaw....................................*Periophthalmodon*

2b. A Single row of teeth on upper jaw..3

3a. Fine compressed teeth; 1 recurved symphyseal canine teeth on each side of lower jaw..*Boleophthalmus*

3b. Larger pointed teeth on lower jaw; no recurved symphyseal canine teeth on lower jaw..*Periophthalmus*

1.1.2 Key to Species of *Scartelaos*

There is a single species found in southern Thailand..*S. histophorus* (Valenciennes)

1.1.3 Key to Species of *Boleophthalmus*

There is a single species found in southern Thailand.........*B. boddarti* (Pallas)

1.1.4 Key to Species of *Periophthalmodon*

1a. Pelvic fins completely united into a disk..................*Pn. schlosseri* (Pallas)
1b. Pelvic fins separate...................................*Pn. septemradiatus* (Hamilton)

1.1.5 Key to Species of *Periophthalmus*

1a. Pelvic fins completely united into a disk..2
1b. Pelvic fins separate..3
2a. Posterior margin of first dorsal fin vertically straight...*Ps. chrysospilos* Bleeker
2b. Posterior margin of first dorsal fin with curved shape............*Ps.* species A
3a. Pelvic fins with frenum...4
3b. Pelvic fin without frenum..5
4a. Two black stripes on second dorsal fin...*Ps.* cf. *novaeguineaensis* Eggert
4b. A single black stripe on second dorsal fin...*Ps. novemradiatus* (Hamilton)
5a. Many white spots on first dorsal fin; margin usually convex...*Ps. argentilineatus* Valenciennes
5b. Few black spots on first dorsal fin; first dorsal fin rounded shape...*Ps. gracilis* Eggert

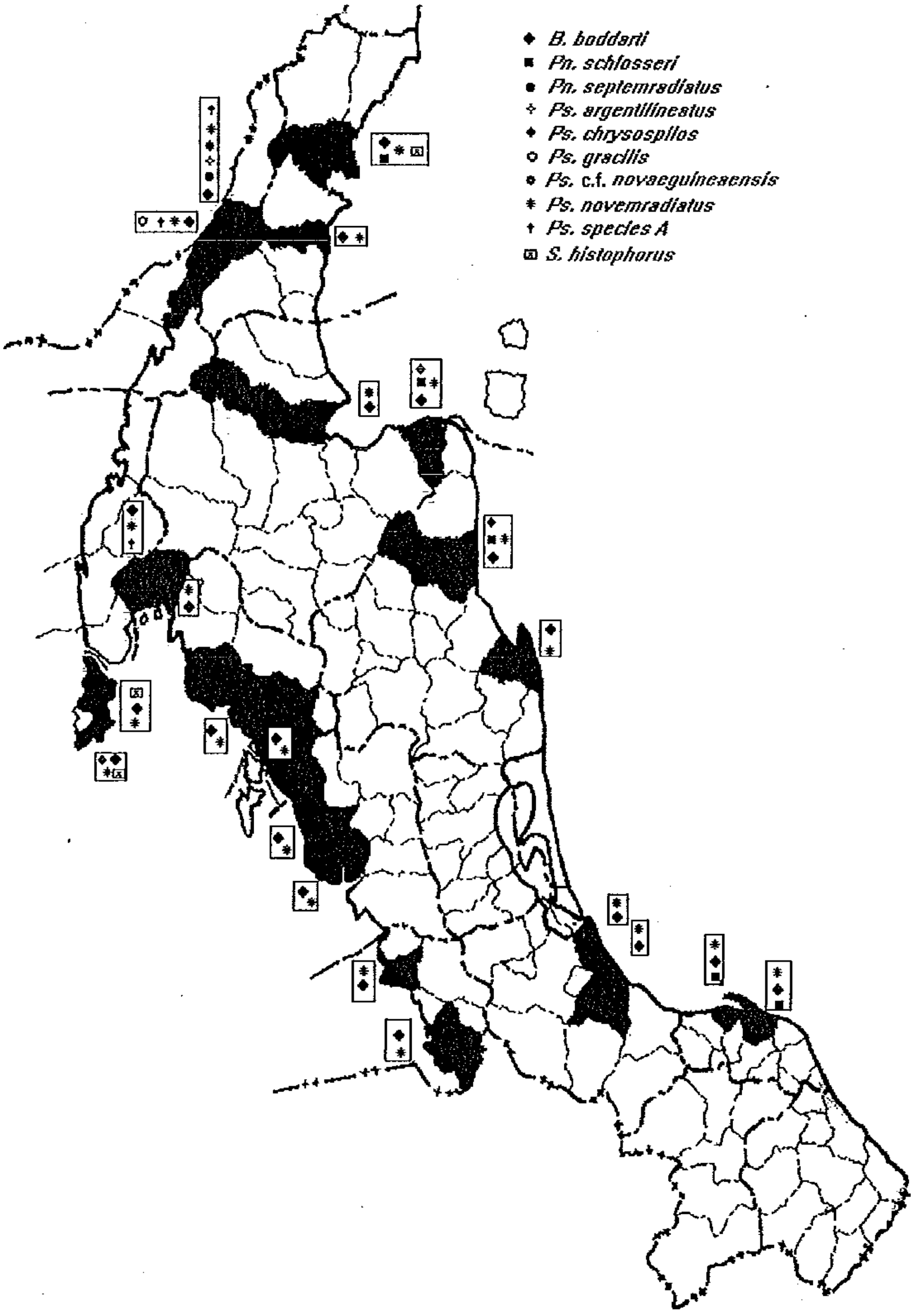

Fig. 3 Known localities of mudskippers in southern Thailand

2. Species descriptions of the Oxudercinae

The distribution, diagnosis and number of the studied specimens, taxonomic description and coloration of freshly dead and preserved specimens of each species of mudskippers are shown below. Their synonyms are quoted from Murdy(1989).

2.1 *Boleophthalmus boddarti* (Pallas), Figure 4

Gobius boddarti Pallas, 1770: 11, pl.2, fig. 14-15 (type locality: Indain Ocean).
Gobius striatus Bloch & Schneiderm, 1801: 71, pl. 16 (type locality: Tranquebar, India).
Gobius plinianus Hamilton, 1822: 45, pl. 35, fig. 13 (type locality: Ganges Delta, India).
Bolephthalmus boddariti Valenciennes in Cuvier & Valenciennes, 1837: 199
(new combination).
Boleophthalmus inormatus Blyth, 1861: 148 (type locality: Tenasserim, India).
Boleophthalmus sculptus Gunther, 1861: 104 (type locality: India).
Apocryptes punctatus Day, 1867: 941 (type locality: Madras, India).

Distribution: Chumporn, Surat-Thani, Nakorn Si Thammarat, Songkhla, Pattani, Trang, Satun, Krabi, Phangnga, Phuket and Ranong.

Diagnosis: One recurved, canine tooth on each side of symphysis, internal to anterior margin of lower jaw; few long pointed teeth vertically on upper jaw symphysis, the rest are small pointed teeth; lower jaw with many small pointed teeth curved horizontally; frenum prominent and strongly connected to outermost pelvic rays; other rays connected by membrane; pelvic fin forms an elliptical disk; D_1 with five spines, the middle longest; first D_2 element is soft spine; the rest are segmented and branched.

Specimens studied:172 specimens with SL range of 39.7-171.7 mm. from all stations .

Description: Proportions: body depth13.1-18.1%SL (mean = 15.4%);
head length 14.2-29.4% SL (mean=26.5%);

head depth 11.5-19.0%SL (mean=16.0%);
head width 13.5-18.7 SL (mean=16.3%);
height of pectoral fin base 4.3-12.7%SL (mean=9.8%);
D_1 base length 4.3-15.2%SL (mean=8.9%);
D_2 base length 33.4-42.5%SL(mean=39.2%);
anal fin base length 34.0-40.4% SL (mean=36.8%;
caudal fin length 8.6-24.5% SL (mean=17.7);
pectoral fin length 11.0-22.2%SL (mean=17.6%);
pelvic fin length 6.6-22.5%SL (mean=14.0%);
caudal peduncle depth 6.6-16.3% SL mean=8.3%).

Meristic counts: pectoral fin rays (left side) 17-21 (mean=18.4);
pectoral fin rays 9 (right side) 17-21 (mean=18.6);
longitudinal scales 67-106 (mean=79.2)
transverse scales 16-33 (mean=19.9);
predorsal scales 25-44 (mean=32.0);
D_1 with 5 rays (mean=5);
total D_2 elements 21-27 (mean=24.2);
total anal fin elements 19-27 (mean 24.1).

Coloration: Based on freshly dead specimens:
background color on head and trunk greenish-brown or greenish-yellow dorso-laterally, white or pale yellow on abdomen; numerous bright blue spots on the head, trunk, D_1 fin, D_2 fin and densely on latero-ventral origin of pectoral fins; seven dark brown or black bands diagonally across the trunk, the first at D_1 base, the second between D_1 and D_2, almost to the end of the pectoral fins, the third, fourth, fifth underneath D_2 base, the sixth at posterior end of D_2 base, and the last at origin

of outermost point of caudal fin element to posterior end of anal fin base; ground color of D_1 greenish-brown, bright blue on connected membrane marginally, numerous bright blue spots on D_1; ground color on D_2 greenish- brown, numerous bright spots on D_2.

Ground color of preserved specimens:

Head and trunk with dark gray color dorso-laterally, white or pale yellow on abdomen; dark gray from jaw origin to lower lip ventrally; seven black bands diagonally cross the trunk as previously described.

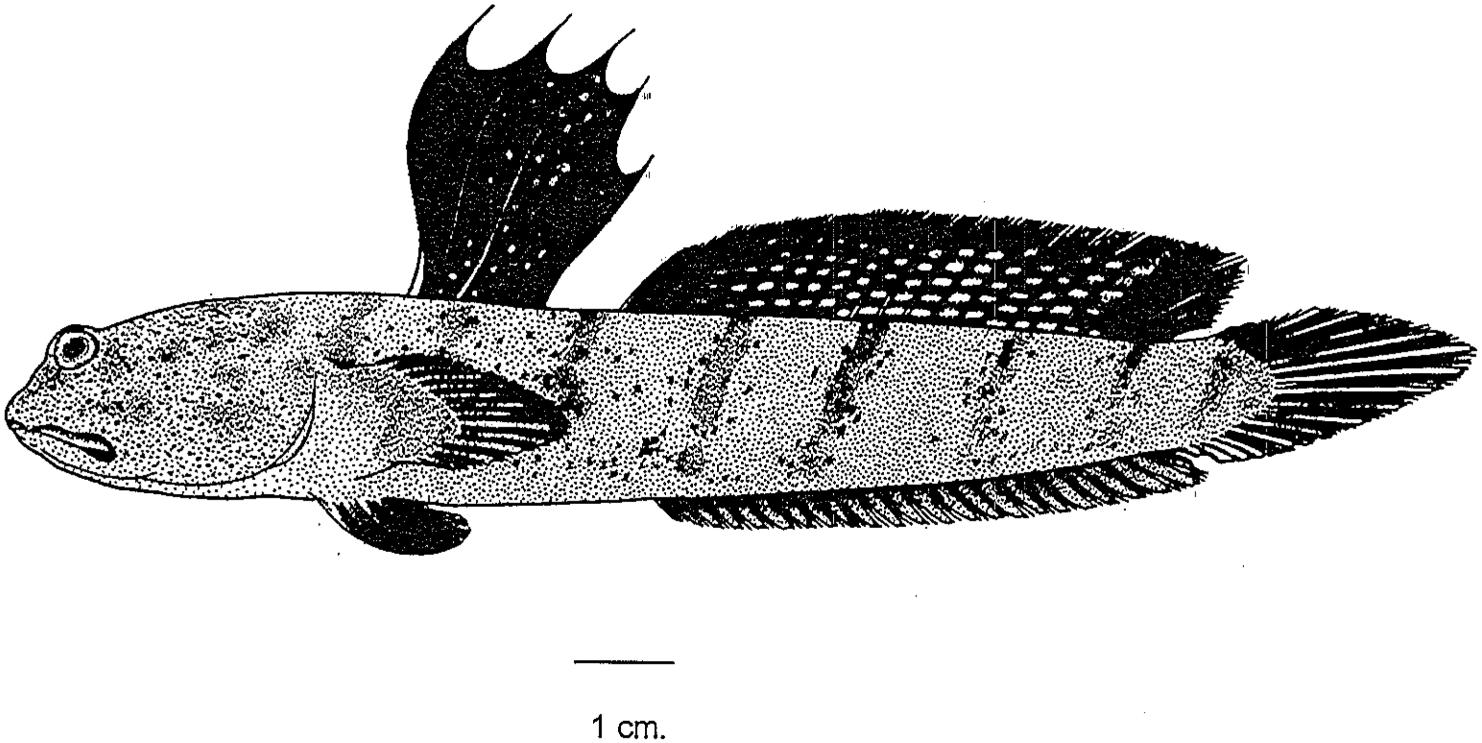

Fig. 4-*Boleophthalmus boddarti* (Pallas), 129.0 mm. SL.

2.2 *Periophthalmodon schlosseri* (Pallas), Figure 5

Gobius schlosseri Pallas, 1770: 5, fig 1-4, pl. 1 (type locality: Ambon, Indonesia).
Periophthalmus ruber Bloch & Schneider, 1801: 64 (type locality: Tranquebar, India).
Periophthalmus schlosseri Bloch & Schneider, 1801: 64 (new combination).
Periophthalmodon schlosseri Bleeker, 1874: 327 (new combination).
Periophthalmus phya Johnstone, 1930: 296, fig 1 (type locality: Jambu, Malaysia).
Periophthalmus schlosseri argentiventralis Eggert,1935: 49 (type locality: Jakerta, Indonesia).

Distribution: Chumporn, Surat-Thani, Nakorn Si Thammarat and Pattani.

Diagnosis: Two rows of teeth on upper jaw; outer row of teeth with enlarged canine teeth; inner row of teeth with small canine teeth; origins of both the inner row of teeth and the outer row of teeth close to each other; frenum strongly prominent; rays of pelvic fin connected by membrane; pelvic fin forms a rounded disk; D_1 margin has a round-curved shape; D_1 rays are spinous; first D_2 and first anal rays are soft and spinous; the rest are segmented and branched; eyes strongly prominent on head; snout and inter-orbital with small scales; two mounds strongly prominent on snout, especially the one closest to inter-orbital; numerous granulae on snout.

Specimens studied: 20 specimens with SL range 75.20-251.30 mm. from Chumporn, Surat-Thani, Nakhorn Si Thammarat and Pattani

Description: Proportions: body depth with 14.2-16.1%SL (mean=15.1%);
head length 26.3-29.7%SL (mean=28.0%);
head depth 16.2-19.7%SL (mean=18.1%);
head width 15.0-22.4%SL (mean=18.4%);
height of pectoral fin base 10.7-14.5%SL

(mean= 12.8%);
D_1 base length 7.4-17.2% SL (mean=13.3%);
D_2 base length 18.5-28.3%SL (mean=21.4%);
anal fin base length 18.0-23.2%SL (mean=20.5%);
caudal fin length 12.8-18.6%SL (mean=14.9%);
pectoral fin length 20.7-26.6%SL (mean=24.0%);
pelvic fin length 13.2-16.4%SL (mean=14.6%);
caudal peduncle depth 8.7-10.4%SL
(mean=9.6%).

Meristic counts: pectoral fin rays (left side) 12-18 (mean=14.8);
pectoral fin rays (right side) 12-17 (mean=14.0);
longitudinal scales 53-62 (mean=51.7)
transverse scales 12-20 (mean=14.0);
predorsal scales 19-35 (mean=21.9);
D_1 with 6-11 rays (mean=7.4);
total D_2 elements 11-13 (mean=11.1);
total anal fin elements 11-13 (mean 11).

Coloration: Based on freshly dead specimens:
background color on head and trunk greenish-brown, some are greenish pink; black stripes coming from eyes posteriorly on dorsal trunk, terminating at the end of D_2 base; pale yellow spots on ventral half of body including operculum and pectoral fins; background color of D_1 is greenish brown; dorsoanterior margin of D_1 with pale yellow or white, single black or brown stripe on the middle of D_2; pale yellow or pale pink on D_2 margin dorsally and ventrally.

Ground color on preserved specimens:
black or dark gray dorsally, white or pale yellow on trunk

ventrally; two stripes located on both sides of dorsal trunk from eyes posteriorly to D_2 end ventrally; D_1 with black or dark brown and white on dorsoanterior margin; D_2 with a single black or dark brown stripe.

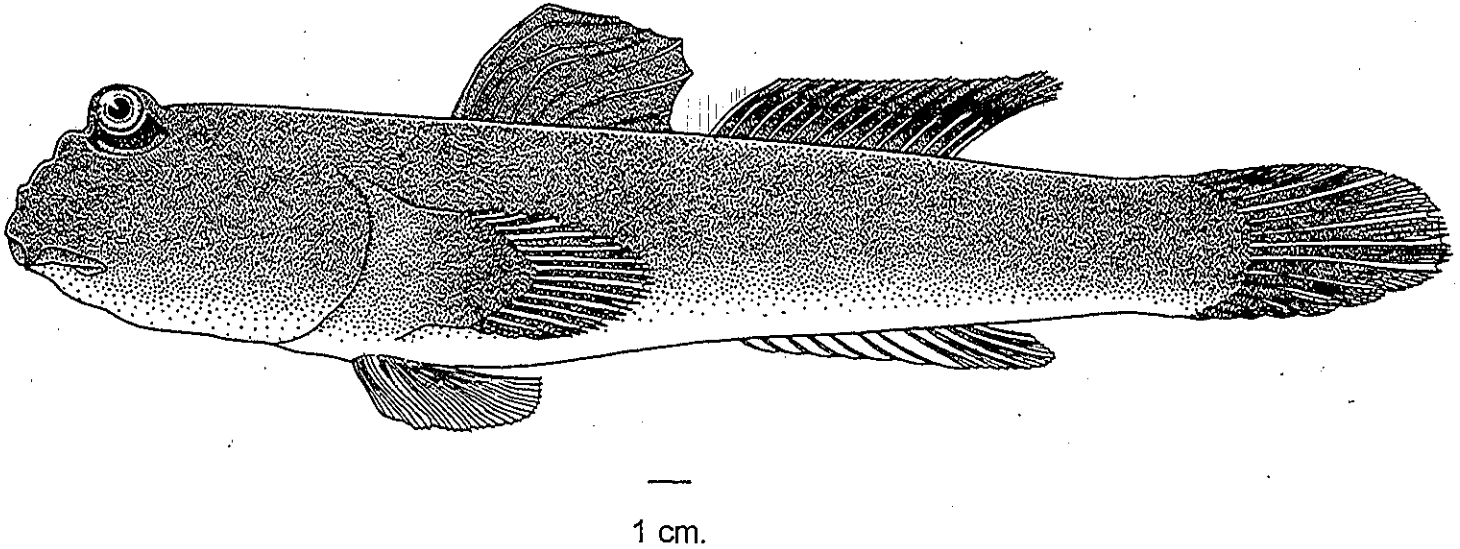

Fig. 5-*Periophthalmodon schlosseri* (Pallas), 220 mm. SL.

2.3 *Periophthalmodon septemradiatus* (Hamilton), Figure 6

Gobius septemradiatus Hamilton, 1822: 46 (type locality: near Ganges Delta).

Gobius tredecemradiatus Hamilton, 1822: 48 (type locality: near Ganges Delta).

Periophthalmus borneensis Bleeker, 1851b: 11 (type locality: Banjermassing, Kalimantan).

Distribution: Ranong

Diagnosis: Two rows of teeth on upper jaw; pelvic fin lacks frenum and separates into fin bases; lacks D_1 fin in female; first spine of D_1 clearly longest in male; posterior margin of D_1 convex; D_2 with a single black stripe; rounded caudal fin.

Specimens studied: 3 specimens with SL range 61.40-69.95 mm. from Ranong.

Description: Proportions: body depth 14.4-15.4%SL (mean=15.1%);
head length 25.5-26.2%SL (mean=25.8%);
head depth 17.7-19.7%SL (mean=18.9%);
head width 16.6-18.9%SL (mean=18.1%);
height of pectoral fin base 10.5-13.2%SL (mean=11.9%);
D_1 base length 0.00-17.5% SL (mean=10.2%);
D_2 base length 18.8-23.5%SL (mean=21.1%);
anal fin base length 13.9-15.9%SL (mean=14.8%);
caudal fin length 13.1-15.4%SL (mean=14.5%);
pectoral fin length 22.0-23.0%SL (mean 22.4%);
pelvic fin length 12.5-13.5%SL (mean=13.3%);
caudal peduncle degth 7.3-8.8%SL(mean=8.1%)

Meristic counts: pectoral fin rays (left side) 13-14 (mean=13.7);
pectoral fin rays (right side)13-13 (mean=13);
longitudinal scales 56-59 (mean=57.7);

transverse scales 14-23 (mean=17.3);
predorsal scales 18-21(mean=20.0);
D_1 with 4-12 rays (mean=8.7);
total D_2 elements 11-14 (mean=12.7);
total anal fin elements 11-12 (mean 11.3).

Coloration: Based on freshly dead specimens:
background color on head and trunk brownish-gray or yellowish-brown dorsolaterally; pale yellow or pale brown on venter; black stripes coming from eyes and lying posteriorly on dorsal trunk, terminating at the end of D_2 base; many bright yellow, black, and blue spots on operculum; pelvic fins yellowish black; pelvic fin margin yellow; pectoral fins bright; D_1 with a black stripe inframarginally; red stripes on D_1 marginally, D_1; D_2 margin with red band; a single black stripe along the middle of D_2 runs horizontally; caudal fin with yellow blotch posteriorly; black blotches on caudal girdle and at caudal ray origin.
Ground color of preserved specimens:
dark brown or dark grey on head and trunk dorsolaterally, white on venter; black stripes coming from eyes posteriorly extending across the dorsal trunk, and ending at D_2 base; black blotches on head, trunk and pectoral fins; pelvic fin yellowish white; D_1 with a black stripe inframarginally; a few black spots near the D_1 base; narrow transparent bar on the margin of D_1; D_2 margin pale; a single black stripe in the middle of D_2 horizontally; black blotches on caudal girdle and at caudal ray origin.

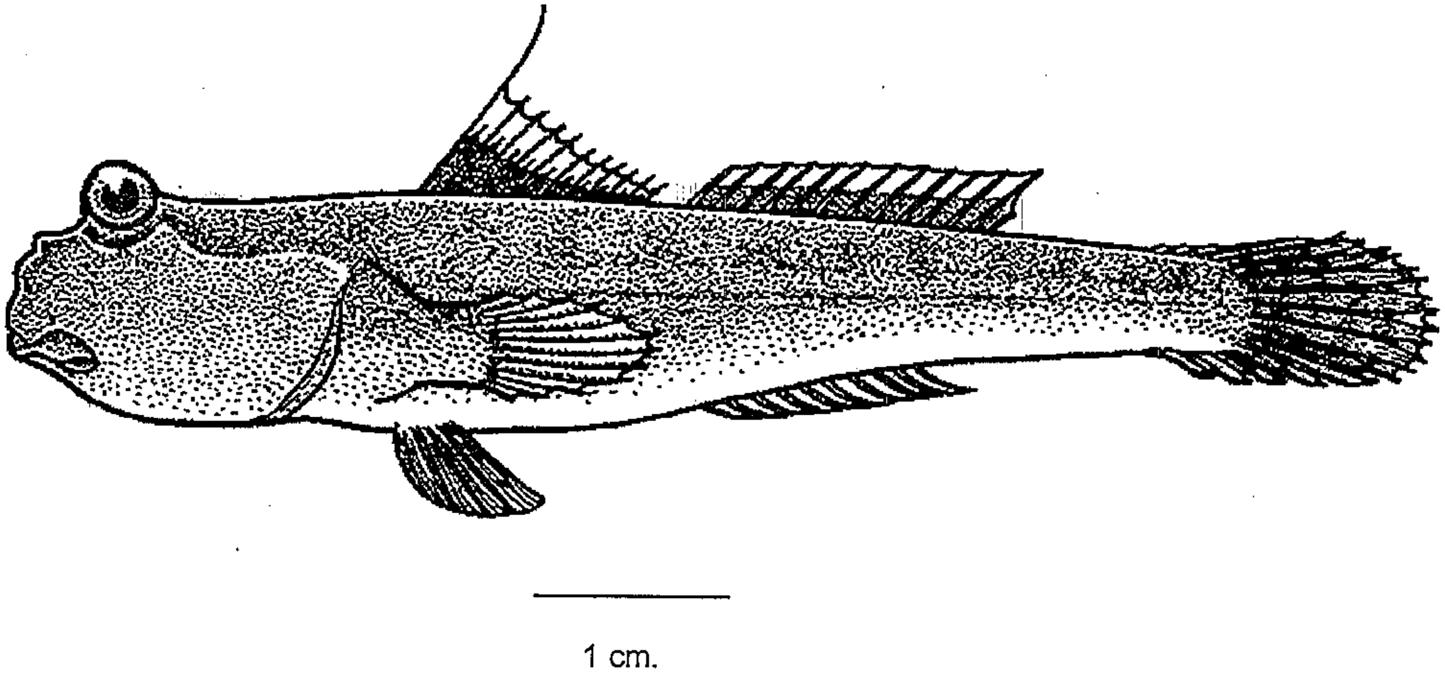

Fig. 6-*Periophthalmodon septemradiatus* (Hamilton), 64.0 mm. SL.

2.4 *Periophthalmus argentilineatus* Valenciennes, Figure 7

Periophthalmus argentilineatus Valenciennes in Cuvier & Valenciennes, 1837: 191
(type localities: Irian Jaya and Moluccas, Indonesia).
Periophthalmus dipus Bleeker, 1854: 320 (type localities: Java and Sumatra, Indonesia).
Euchoristopus kalolo regius Whitley, 1931: 326 (type locality: northwestern Australia).
Peripohthalmus vulgaris vulgaris Eggert, 1935: 81, pls 6-7. figs 23-28
(type locality: Buru, Moluccas, Indonesia).
Periophthalmus vulgaris notatus Eggert, 1935: 83 pl. 7, fig 29
(type locality: Sungei, Malysia).
Periophthalmus vulgaris rigius.-Eggert, 1935: 84, 84 pl. 7, fig. 30 (new combination).
Periophthalmus vulgaris ceylonensis Eggert, 1935: 85 (type locality: Sri Lanka).
Periophthalmus dipus parvus Eggert, 1935: 88, pl. 8, fig. 32
(type locality: Belawan, Sumatra, Indonesia).
Periophthalmus dipus angustiformis Eggert, 1935: 89, fig.14
(type locality: Flores, Java, Indonesia).
Periophthalmus argentilineatus striopunctatus Eggert, 1935:94.pl.9,fig.36
(type locality: Balikpapan, Kalimantan, Indonesia)
Periophthalmus sobrinus Eggert, 1935: 95, pl.9, figs 37-38
(type locality: southwestern Red Sea).

Distribution: Ranong

Diagnosis: Pelvic fins with no frenum; medialmost pelvic fin rays not united by membrane; posterior margin of D_1 straight or slightly convex; a single black stripe on D_1 inframarginally; numerous small white spots on D_1 basally; D_2 with a single black stripe medially; many white spots on D_2 base.

Specimens studied :17 specimens with SL range 42.10-60.90 mm.
from Ranong.

Description: Proportions: body depth 11.8-17.5%SL (mean=13.4%);
head length 23.6-30.3%SL (mean=25.2%);
head depth 14.4-18.4%SL (mean=16.9%);

head width 14.7-17.7%SL (mean = 16.5%);
height of pectoral fin base 9.3-18.7% SL (mean = 10.5%);
D_1 base length 13.6-19.6% SL (mean = 16.9%);
D_2 base length 19.1-23.6%SL (mean =21.1%);
anal fin base length 17.2-20.2%SL (mean=18.9%);
caudal fin length 17.1-20.2%SL (mean=18.6%);
fin length 20.1-25.2%SL (mean 22.7%);
pelvic fin length 10.2-23.0%SL (mean=12.3%);
caudal peduncle depth 6.6-7.8%SL (mean=7.3%);

Meristic counts: pectoral fin rays (left side) 10-12 (mean=11.0);
pectoral fin rays (right side)10-12 (mean=10.9);
longitudinal scales 57-76 (mean=66.1);
transverse scales 13-18 (mean=15.4);
predorsal scales 21-30(mean=26.4);
D_1 with 7-11 rays (mean=9.5);
total D_2 elements 10-13 (mean=12.4);
total anal fin elements 11-13 (mean 11.7).

Coloration: Based on freshly dead specimen:
background color pale brown or yellowish-white on head and trunk; pale yellow or silvery white on venter; some black blotches on head and trunk; narrow silvery bars from venter up almost to midline; numerous white or silvery spots on operculum ventrally; outer margin of pelvic fins yellow and inner area with black blotch; D_1 red or brownish red dorsomarginally; numerous white or silvery spots near D_1 base; D_2 margin with red or brownish red band; a single black solid stripe on D_2; white spots on D_2 basally.

Ground color of preserved specimens:
pale grayish-brown on head and trunk; white on venter; many narrow silvery bars from venter up almost to midline; a single black stripe on D_1 inframarginally; numerous small white spots on D_1 basally; D_2 with a single black stripe medially; many white spots on D_2 basally.

Remark: This species is also reported to inhabit mangrove areas in the Songkhla Lake. The specimens were collected by scoop net and deposited at National Institute for Coastal Aquaculture, Songkhla Province (Sirimontaporn, 1993).

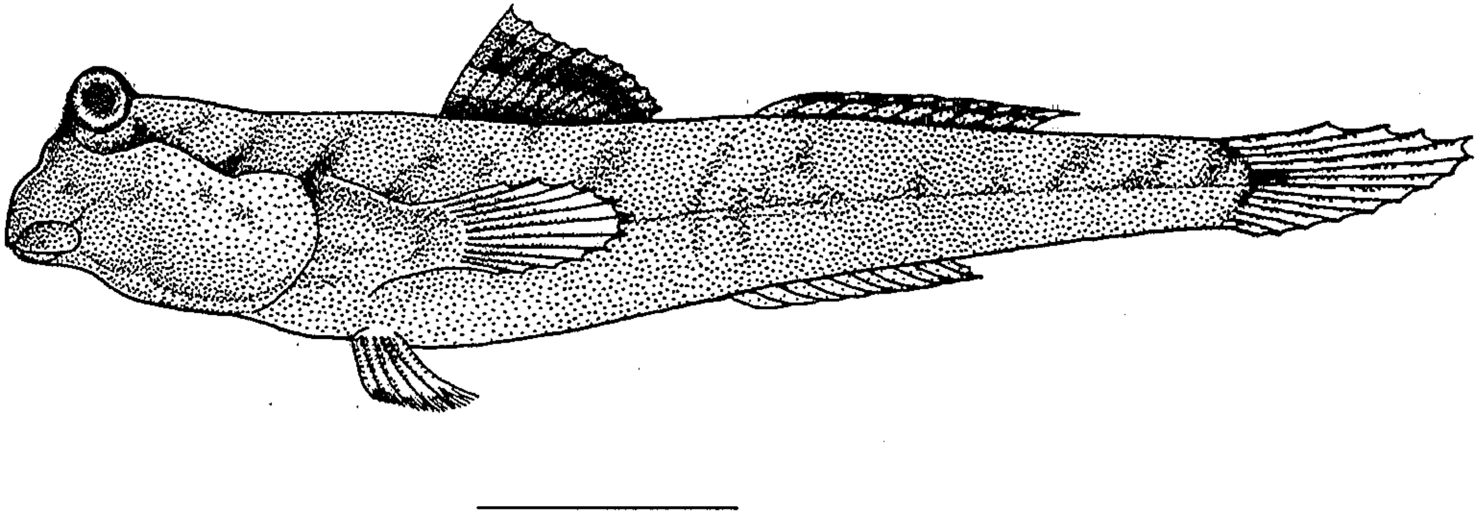

Fig. 7-*Periophthalmus argentilineatus* Valenciennes, 48.0mm.SL.

2.5 *Periophthalmus chrysospilos* Bleeker, Figure 8

Periophthalmus chrysospilos Bleeker, 1852: 728 (type locality: Banka Island, Indonesia)

Distribution: Phuket, Nakorn Si Thammarat, Surat-Thani, Satun

Diagnosis: Frenum prominent and strongly connected to outermost pelvic rays; innermost pelvic fin rays united by a membrane to form a rounded disk; anterior margin of D_1 straight diagonally and posterior margin of D_1 vertically straight forming a triangular shape; first spine of D_1 clearly longest in male; a single dark stripe on D_2 mesially.

Specimens studied: 44 specimens with SL range 42.9-77.8 mm.
from Phuket, Nakhorn Si Thammarat and Surat-Thani.

Description: Proportions: body depth 12.0-20.0%SL (mean=14.5%);
head length 22.7- 26.7% SL (mean=24.7%);
head depth 12.4-16.3%SL (mean=14.5%);
head width 14.1-18.4%SL (mean = 15.5%);
height of pectoral fin base 8.9-11.5% SL (mean = 10.3%);
D_1 base length 5.4-16.7% SL (mean = 10.5%);
D_2 base length 17.5-23.9%SL (mean=20.4%);
anal fin base length 14.7-20.9%SL (mean=18.2%);
caudal fin length 10.7-24.3%SL (mean=20.9%);
pectoral fin length 18.6-27.3%SL (mean 23.2%);
pelvic fin length 10.3-15.5%SL (mean=13.2%);
caudal peduncle depth 7.3-8.5%SL (mean=7.9%)

Meristic counts: pectoral fin rays (left side) 13-15 (mean=13.9);
pectoral fin rays (right side) 12-15 (mean=14.1);
longitudinal scales 64-82 (mean=72.8);

transverse scales 17-21(mean=18.5);
predorsal scales 21-32(mean=26.8);
D_1 with 6-11 rays (mean=7.3);
total D_2 elements 10-14 (mean=12.3);
total anal fin elements 10-13 (mean 11.4).

Coloration: Based on freshly dead specimens:

background color on head and trunk gray or pale gray; pale yellow or white on venter; numerous orange or yellow spots on head ventrally, lips, snout, operculum, pectoral fins, pelvic fins, and laterally on trunk; first spine black and tip of first spine red; interspinous membrane of D_1 basally red and distally black with a white margin; the rest of spines pale yellow or whitish going diagonally; background color on D_2 pale yellow or white; distal margin of D_2 red; a single black or brown stripe on D_2 mesially.

Ground color of preserved specimens:

head and trunk dark gray dorsolaterally; pale yellow or white ventrally; numerous white sports on head ventrally, lips, snout, operculum pectoral fins, pelvic fins, and laterally on trunk; D_1 margin with black band posteriorly; single black stripe on D_2 mesially; anal fin with bright yellow ;caudal fin with pale black.

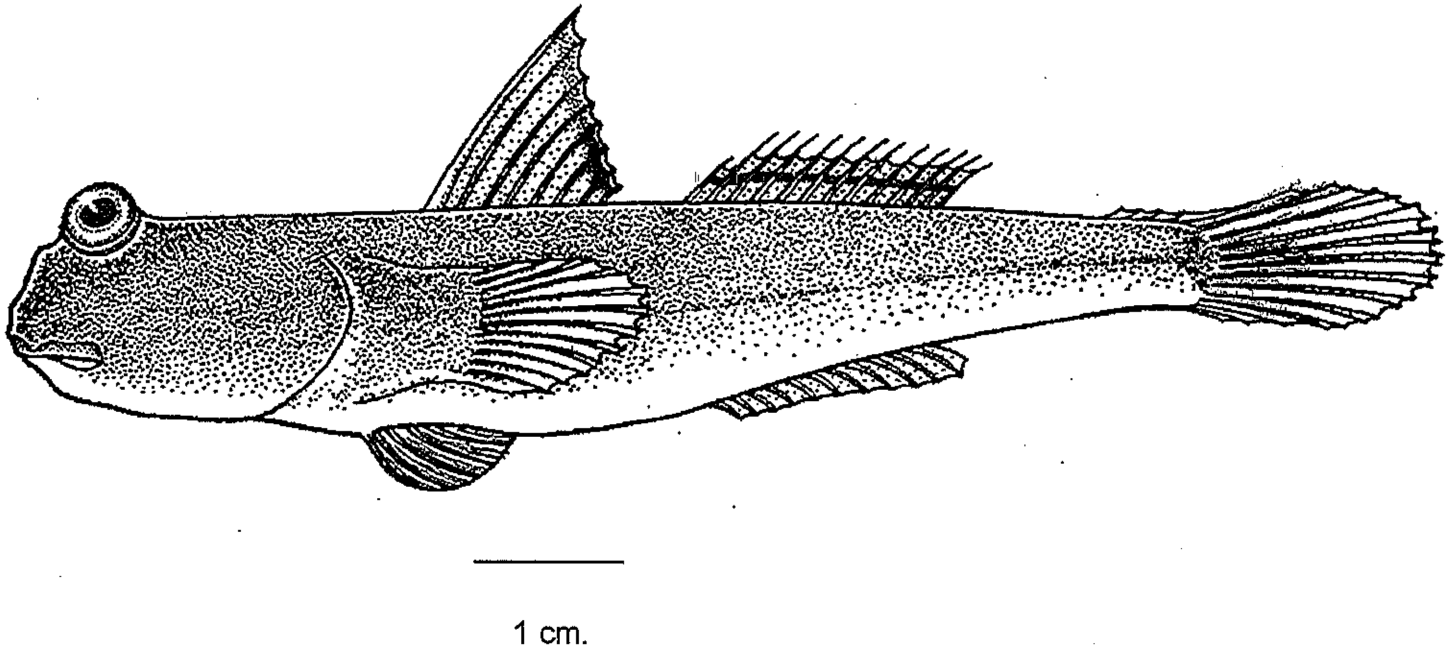

Fig. 8-*Periophthalmus chrysospilos* Bleeker, 81.0 mm. SL.

2.6 *Periophthalmus gracilis* Eggert 1935, Figure 9

Periophthalmus gracilis Eggert, 1935: 79, pl.6, fig. 22
(type locality: Java and Sumatra, Indonesia).

Distribution: Ranong

Diagnosis: Lacking or no frenum; pelvic fins separate; D_1 short and rounded, rounded caudal fin; single stripe on D_2 mesially.

Specimens studied: 10 specimens with SL range 36.35-77.55 mm.from Ranong

Description: Proportions: body depth 10.7-12.8%SL (mean=12.0%);
head length 22.6-23.7%SL (mean=23.1%);
head depth 13.1-14.3%SL (mean=13.7%);
head width 15.0-17.5%SL (mean = 16.2%);
height of pectoral fin base 8.4-9.3% SL (mean = 8.9%);
D_1 base length 17.7-20.4% SL (mean = 19.3%);
D_2 base length 17.7-20.4%SL (mean = 19.3%);
anal fin base length 16.2-19.1%SL (mean=17.9);
caudal fin length 18.9-20.2%SL(mean=19.6%);
pectoral fin length 20.2-22.7%SL (mean 21.4%);
pelvic fin length 10.4-11.8%SL (mean=11.0%);
caudal peduncle depth 6.6-7.5%SL (mean=7.0%)

Meristic counts: pectoral fin rays (left side) 10-13 (mean=11.3);
pectoral fin rays (right side) 10-12 (mean=11.2);
longitudinal scales 52-70 (mean=61.1);
transverse scales 13-19 (mean=15.3);
predorsal scales 18-30 (mean=24.7);
D_1 with 8-13 (mean=10.4);

total D_2 elements 11-13 (mean=11.8);
total anal fin elements 10-12 (mean 10.56).

Coloration : Based on freshly dead specimens:
background color on head and trunk yellowish brown dorsolaterally; white or pale brown on venter; many white or pale brown spots on operculum, densely on lateroventral part; black blotch on operculum insertion; many silvery white bars on lower half of trunk ventrolaterally; 7-8 diagonal black bars on trunk dorsolaterally; D_1 short with thin, transparent margin, and a broad black band inframaginally, small red spots on D_1 basally; D_2 with pale red margin, and bright transparent band inframarginally, a single black stripe on D_2 mesially; pectoral fin bright brown; pelvic fin yellow and immaculate; colorless on anal fin; many black blotches on caudal fin rays and interspinous membrane.

Ground color of preserved specimens:
dark brown on head and trunk dorsolaterally, pale brown or white on venter, many silvery white bars on trunk ventrolaterally; 7-8 diagonal black blotches on trunk dorsolaterally; D_1 with bright and transparent margin; broad black band inframarginally on D_1, small white spots on D1 basally; D_2 margin bright, with a single black stripe on D_2 mesially; pectoral fin bright brown; pelvic fin pale yellow; colorless anal fin; many black blotches on caudal rays and interspinous membrane.

Remark: This species is also reported to inhabit the Songkhla Lake, though it is very rare there. Five specimens were collected by set bags and deposited at National Institute for Coastal Aquaculture, Songkhla Province by Sirimontaporn (1993)

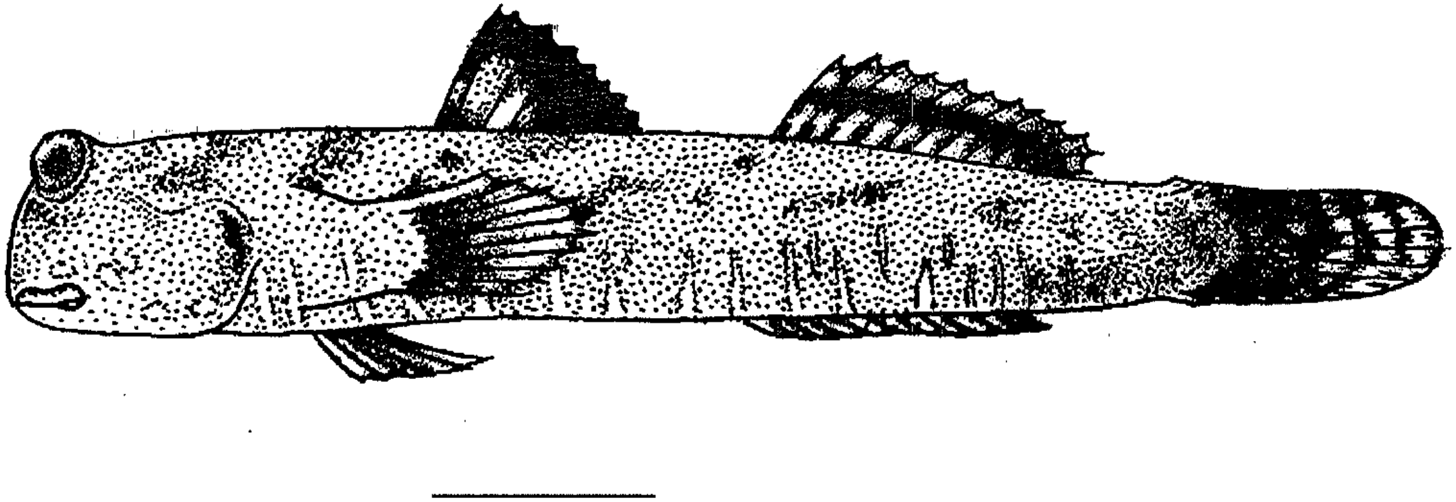

Fig. 9-*Periophthalmus gracilis* Eggert, 55 mm. SL.

2.7 *Periophthalmus* cf. *novaeguineaensis* Eggert, Figure 10

Periophthalmus cantonensis novae-guineaensis Eggert 1935: 61, fig 2, pl3, fig. 12
(type locality: Meruake, Irain, Java, Indonesia).
Periophthalmus expeditionium Whitley, 1935: 127, fig. 2,
(type locality: Gulf of Carpentaria, Queensland).

Distribution: Ranong

Diagnosis: Frenum prominent; pelvic fins do not form disk, pelvic fins united by membrane for at least two thirds of their lengths; first first two spines of D_1 clearly longest in male; anterior margin of D_1 straight vertically; posterior margin of D_1 slightly convex; D_2 with two black stripes horizontally; rounded caudal fin.

Species studies: 25 specimens with SL range 43.65-68.70 mm. from Ranong.

Description: Proportions: body depth 12.1-15.1%SL (mean=13.3%);
head length 23.1-25.7% SL (mean=24.1%);
head depth 15.5-16.7% SL (mean=16.1%);
head width 10.0-17.3%SL(mean =15.9%);
height of pectoral fin base 9.0-11.3% SL (mean = 10.2%);
D_1 base length 9.8-21.9% SL(mean =17.7%);
D_2 base length 19.5-23.1%SL (mean = 21.8%);
anal fin base length 18.8-22.6%SL (mean=21.0%);
caudal fin length 17.0-21.3%SL (mean=18.6%);
pectoral fin length 20.3-25.6%SL (mean 22.7%);
pelvic fin length 8.9-11.1%SL (mean=9.9%);
caudal peduncle depth 6.7-8.0%SL (mean=7.4%).

Meristic counts: pectoral fin rays (left side) 10-16 (mean=12.3);
pectoral fin rays (right side) 11-15 (mean=12.3);
longitudinal scales 69-88 (mean=78.5);
transverse scales 16-20 (mean=17.8);
predorsal scales 25-35(mean=29.7);
D_1 with 8-10 rays(mean=9.1);
total D_2 elements 11-14 (mean=12.8);
total anal fin elements 12-14 (mean 13.4).

Coloration: Based on freshly dead specimens:

background color on head and trunk yellowish brown; pale yellow on venter; black blotches and golden spots on head ventrolaterally; six blotches on trunk dorsolaterally, first at anterior of D_1 base to pectoral fin insertion, second at end of D_1 base, third anterior to D_2 base, fourth at mid-point of D_2 base, fifth close to end of D_2 base, sixth on caudal peduncle; D_1 posterior margin with narrow colorless bar; ground color of D_1 greenish yellow; D_1 margin with red blotch anterior to third spine; D_2 margin pale red dorsally; two black stripes sandwiching bright green stripe; narrow red stripes at both dorsal and ventral margins of green stripe; anal fin with pale red; pectoral girdle and pectoral rays origin of red color; pelvic fins yellowish brown marginally, black blotch on interior.

Background color of preserved specimens:

dark gray or dark brown on head and trunk dorsolaterally; pale yellowish white on ventral trunk; pale violetish gray on ventral head; six black blotches in positions previously described; ground color of D_1 dark gray, white or bright on posterior margin; colorless on D_2 margin, two black stripes sandwiching colorless band mesially; anal fin and pectoral fin colorless.

Remarks: This species is closest to the description of *Ps. novaeguineaensis* in the taxonomic revision by Murdy (1988). However certain characteristics of our specimens are quite different to *Ps. novaeguineaensis* previously described. The posterior margin of D_1 of our specimens is slightly convex, but the margin of D1 of *Ps. novaeguineaensis* in the paper by Murdy 1988 is slightly rounded. The first two spines of D_1 in males are longest, while Murdy stated that D_1 has no elongate spines.

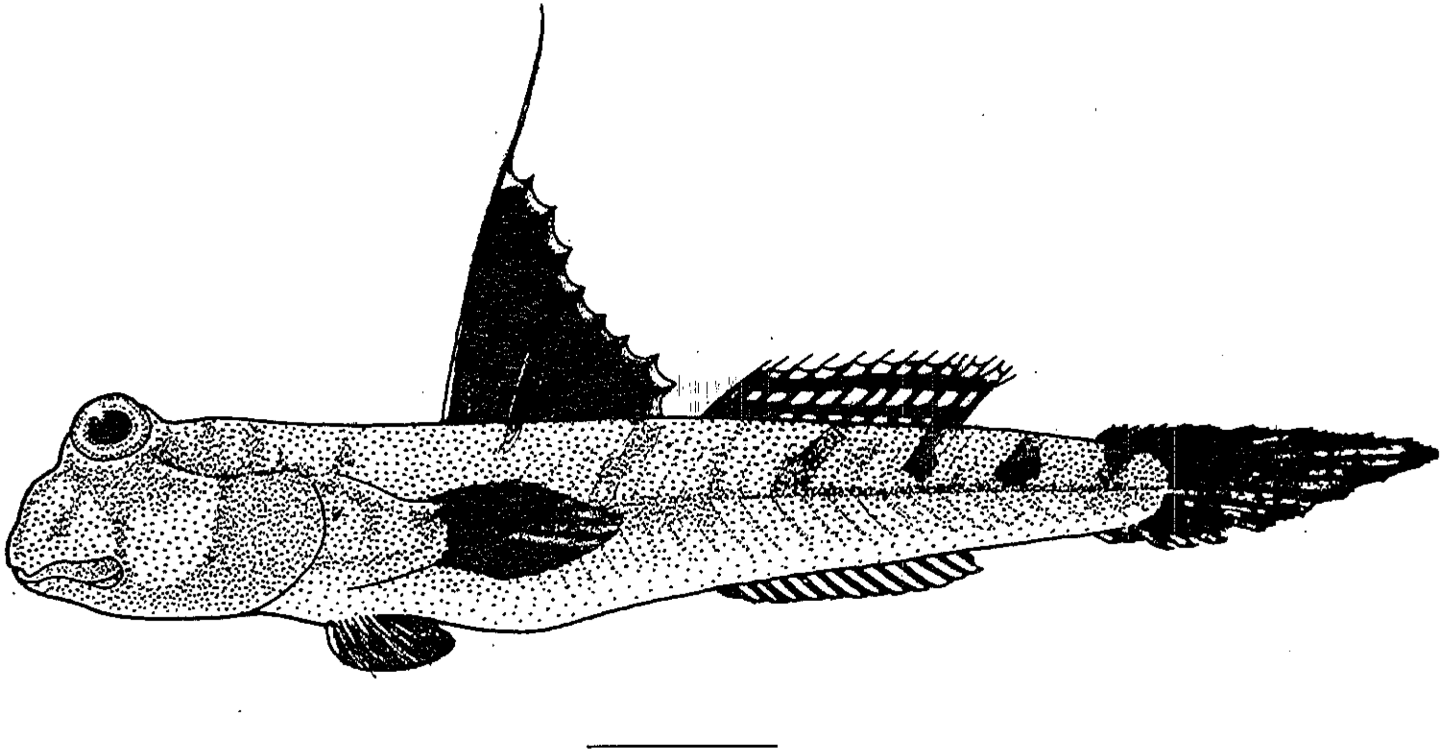

Fig. 10-*Periophthalmus* cf. *novaeguineaensis* Eggert, 47.0 mm. SL.

2.8 *Periophthalmus novemradiatus* (Hamilton), Figure 11

Gobius novemradiatus Hamilton, 1822: 47, pl. 2, fig. 14
(type locality: vicinity of Calcutta).
Periophthalmus novemradiatus Valenciennes in Cuvier & Valenciennes, 1837: 148
(new combination).
Periophthalmus pearsei Eggert, 1935: 57, pl.3, fig. 10
(type locality, Port Canning, India).
Periophthalmus variablilis variablilis Eggert, 1935: 64, fig. 5, pl. 3, fig. 13
(type locality, Java, Indonesia).
Periophthalmus variablilis sumatranus Eggert, 1935: 65, fig. 6, pl. 4, figs 14-15
(type locality, Balawan, Sumatra, Indonesia).
Periophthalmus variablilis asiaticus Eggert, 1935: 66, fig. 7
(type locality: Paknam, Thailand).
Periophthalmus variablilis tidemani Eggert, 1935: 67, fig. 8
(type locality: Halmahera, Moluccas, Indonesia).

Distribution: Chumporn, Surat-Thani, Nakhorn Si Thammarat, Songkhla, Pattani, Satun, Trang, Krabi, Phangnga, Phuket, Ranong.

Diagnosis: Pelvic fin with frenum but not strongly prominent, pelvic fins separate about 2/3 distance posteriorly; first spine of D_1 straight, D_1 posterior margin convex; single black stripe on D_2 mesially; slightly rounded causal fin.

Specimens studied: 92 specimens from with SL range 23.1-96.3 mm. from all stations.

Description: Proportions: body depth 11.8-19.1%SL (mean=14.1%);
head length 17.3-26.4%SL (mean=24.3%);
head depth 11.8-19.1%SL (mean=16.7%);
head width 13.8-22.7%SL (mean=17.3%);

height of pectoral fin base 8.9-25.3%SL (mean=10.8%);
D_1 base length 11.0-23.1%SL(mean = 17.1%);
D_2 base length 18.4-25.6%SL (mean = 21.6%);
anal fin base length 15.9-25.9%SL (mean=18.6%);
caudal fin length 7.0-25.6%SL (mean=18.6%);
pectoral fin length 7.6-25.9%SL(mean=22.7%);
pelvic fin length 10.6-17.7%SL(mean=11.8%);
caudal peduncle depth 6.9-19.2%SL (mean=7.8%)

Meristic counts: pectoral fin rays (left side) 9-13(mean=10.9);
pectoral fin rays (right side) 9-13 (mean=10.9);
longitudinal scales 55-75 (mean=64.3);
transverse scales 13-19 (mean=15.7);
predorsal scales 20-30(mean=25.6);
D_1 with 6-13 rays (mean=9.0);
total D_2 elements 10-14 (mean=12.3);
total anal fin elements 9-13 (mean 11.7).

Coloration: Based on freshly dead specimens:

background color on head and trunk brownish-gray or yellowish-brown dorsolaterally; pale yellow or pale brown on venter; black blotches on head, trunk and pectoral fins; black blotch on operculum margin posteriorly; ground color on pelvic fins yellowish-black; pelvic fin margin with yellow; pectoral fins bright yellow; red blotch at the tips; D_1 with black stripe inframarginally; few red spots on D_1 basally; narrow transparant bar mesially on D_1, D_2 margin with red band dorsally; single black stripe on mesial of D_2 horizontally; many red spots on D_2 base; caudal fin with red blotch posteriorly; black blotches on caudal girdle and caudal ray origin.

Ground color of preserved specimens:
dark brown or dark grey on head and trunk dorsolaterally, white on venter, black blotches on head, trunk and pectoral fins dorsolaterally; black blotch on posterior margin of operculum; pelvic fin colorless; D_1 with black stripe inframarginally; few black spots on D_1 base; narrow, colorless bar on mesial of D_1; D_2 margin bright dorsally, single black stripe on mesial of D_2 horizontally; black blotches on caudal girdle and caudal ray origin.

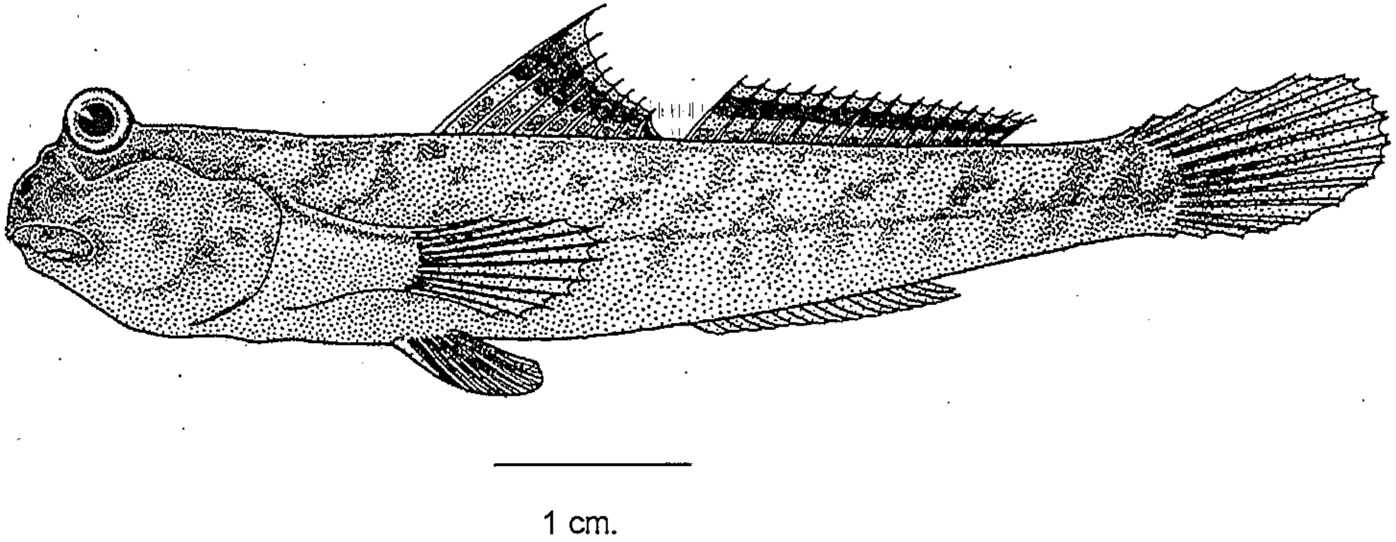

Fig.11-*Periophthalmus novemradiatus* (Hamilton), 60.0 mm. SL.

2.9 *Periophthalmus* species A, Figure 12

Distribution: Ranong and Phangnga

Specimens studied: A specimen with 110.9 mm. SL from Ranong

Dianosis: 26 canine teeth on upper jaw, arranged in a single row; 3 pairs at the front are the largest; the next 2 pairs are slightly smaller, 4 pairs are mid-sized and the last 2 pairs are smallest; 20 teeth on lower jaw in single row with 5 pairs of large canines, next 5 pairs are median canines; snout, isthmus and interorbital region with no scales; frenum strongly prominent and connected to outermost pelvic fin rays; innermost rays connected by membrane to form disk; first dorsal fin margin rounded; first ray of second dorsal fin is spinous; the rest are segmented, and branched; first six rays of anal fin are segmented; the rests are segmented and branched; scales on dorsal head are of cycloid type with many small radii on embedded part but few on exposed part; scales at pectoral fin origin dorsally are of cycloid type but have slightly square shape, radii at embedded part fewer in number but larger than radii of scales on dorsal head; some radii join each other transverely; scales on dorsolateral trunk are of cycloid type with large focus; scales at caudal fin origin have elliptical shape and many small radii on embedded part; two mounds on snout; eyes are large and prominent; lip of upper jaw folded into two layers; the outer membrane has two triangular sheets prominently covering the Inner membrane and lower lip; the inner membrane joined with the lower lip forms a mound at each side of the lower lip.

Specimens studied: 17 specimens with SL range 51.6-118.5 mm.
from Ranong and Phangnga .

Description: Proportions: body depth 12.7-15.0%SL (mean=14.1%);
head length 25.3-28.5%SL (mean=26.8%);
head depth 17.8-21.1%SL (mean=19.5%);
head width 18.5-23.0%SL (20.9%);
height of pectoral fin base 10.4-12.9%SL (mean=11.5%);
D_1 base length 10.1-17.5%SL (mean = 14.9%);
D_2 base length 14.5-21.9%SL (mean = 17.7%);
anal fin base length 14.1-15.8%SL (mean=14.9%);
caudal fin length 12.5-16.5%SL (mean=14.2%);
pectoral fin length 13.4-26.6%SL (mean 22.7%);
pelvic fin length 11.6-14.2%SL (mean = 13.0%);
caudal peduncle depth 7.4-8.8%SL(mean=8.2%)
Meristic counts: pectoral fin rays (left side) 12-15(mean=13.7);
pectoral fin rays (right side) 13-15 (mean=14.0);
longitudinal scales 61-71 (mean=64.0);
transverse scales 12-15 (mean=13.9);
predorsal scales 25-29 (mean=26.7);
D_1 with 7-10 rays(mean=8.4);
total D_2 elements 9-13 (mean=11.4);
total anal fin elements 9-12 (mean 10.4).

Coloration: Based on freshly dead specimens:
background color brownish gray dorsolaterally; pale yellowish-gray on venter; numerous yellow or white spots on head and trunk dorsolaterally; dense on operculum ventrolaterally; five diagono-vertically black blotches on trunk dorsolaterally; first

on head and pectoral fins; second at D_1 base posteriorly; third at D_2 base anteriorly; fourth posterior of D_2 base; fifth at anteriormost of caudal fin; ground color of D_1 with brownish red and white margin; D_2 margin with pale red, single black stripe on D_2 mesially; red spots arranged on D_2 basehorizontally; ground color of pelvic fin with pale yellowish brown; pectoral fins and caudal fin with brown and black blotches on rays; anal fin pale brown.

Ground color of preserved specimens:

head and trunk gray dorsolaterally; white on venter; numerous white spots on head and trunk dorsolaterally, dense on operculum ventrolaterally; ground color of D_1 black dorsally, first D_1 spine white, D_1 margin white dorsally; D_2 margin white, single black stripe on D_2.

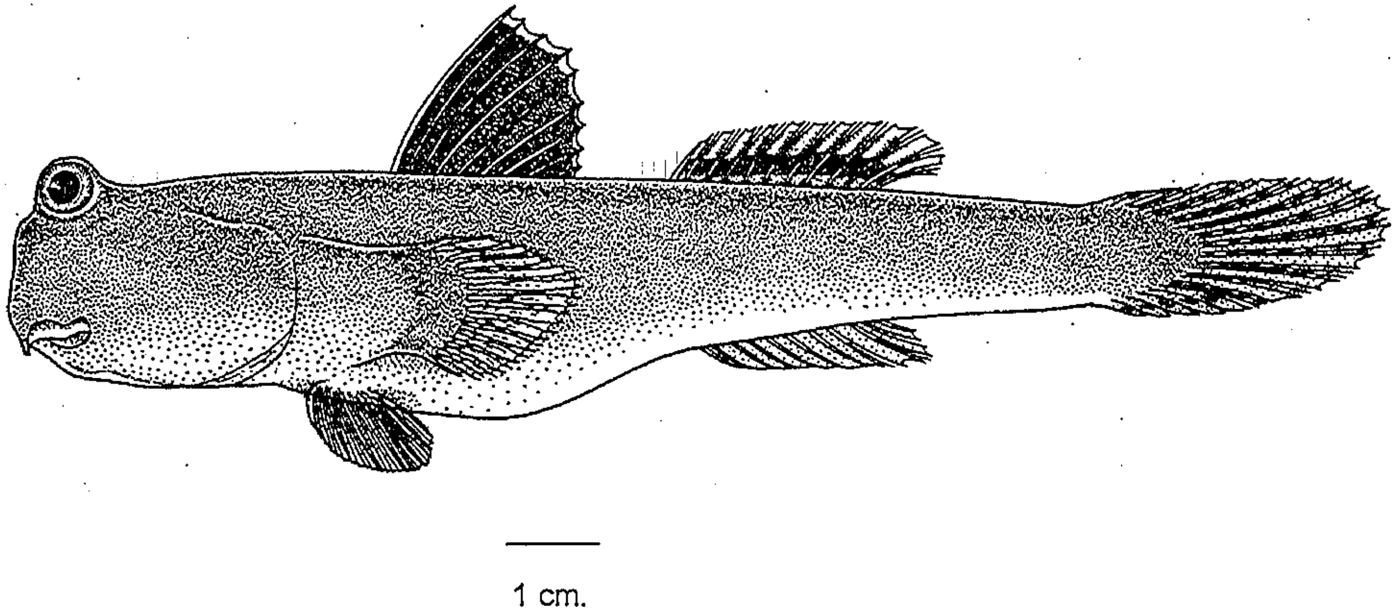

Fig. 12-*Periophthalmus* species A. 127.0 mm. SL.

2.10 *Scartelaos histophorus* (Valenciennes), Figure 11

Gobius viridis Hamiltion, 1822: 42, pl.32, fig. 12
(Type locality: Ganges River, India), A primary homonym of G. iridis Otto, 1821.
Boleophthalmus histophorus Valenciennes in Cuvier & Valenciennes, 1837: 210
(Type locality, Bombay, India).
Bolepohthalmus sinicus Valenciennes in Cuvier & Valenciennes, 1837: 215
(Type locality, Canton, China).
Bolepohthalmus chinensis Valenciennes in Cuvier & Valenciennes, 1837: 215
(Type locality, Canton, China)
Bolepohthalmus aucupatorius Richardson, 1845: 208 (Type locality: China Sea).
Bolepohthalmus campylostomus Richardson, 1845: 209 (Type locality, Canton, China).
Apocryptes macrophthalmus Castelnau, 1873: 87 (Type locality: northern Australia).
Gobiosoma guttulatum Macleay, 1878: 357, pl.9, fig. 6
(Type locality: Port Darwin, Northern Territory, Australia).
Gobiosoma punctularum De Vis, 1884: 445 (Type locality: South Seas).
Boleophthalmus noverguinea Hase, 1914: 535, fig. 8 (Type locality: New Guinea).

Distribution: Chumporn and Phuket

Diagnosis: Barbels present on lower jaw; only single barbel present on mid line of lower jaw symphasis; pointed teeth on upper jaw; many small pointed teeth on lower jaw; elongated body with small head; frenum prominent and connected with the outermost rays of pelvic fin; innermost of pelvic rays connected by membrane to form rounded disk; D_1 with five spinous rays and the middle ray longest; no stripe on D_2; posterior margin of D_2 base connected with caudal fin by a membrane; anal fin base conneted with caudal fin by a membrane.

Specimens studied: 14 specimens with SL range 35.9-113.9 mm.
from Chumporn and Phuket

Description: Proportions: body depth 6.7-10.2%SL (mean=8.0%);
head length 14.8-21.5%SL (mean=17.8%);
head depth 7.6-10.2%SL (mean=8.6%);
head width 8.2-12.2%SL (mean=9.6%);
height of pectoral fin base 4.3-6.2%SL (mean=4.9%);
D_1 base length 2.8-5.5% SL (mean=3.9%);
D_2 base length 37.9-49.9%SL (mean=41.3%);
anal fin base length 34.0-45.6%SL (mean=37.7%);
caudal fin length 17.6-23.1%SL(mean=19.2%);
pectoral fin length 9.0-13.4%SL (mean=10.7%);
pelvic fin length 8.2-11.2%SL (mean=9.7%);
caudal peduncle depth 3.9-5.7%SL (mean=4.6%).

Meristic counts: pectoral fin rays (left side) 17-19 (mean=18.0);
pectoral fin rays (right side) 18-19(mean=18.3);
D_1 with 5 rays (mean=5);
total D_2 elements 26-28 (mean=27.3);
total anal fin elements 25-26 (mean 25.3).

Coloration: Based on freshly dead specimens:

background color on head and trunk grayish white dorsolaterally; snout and operculum dark gray dorsolaterally; many small black spots on head and trunk dorsolaterally and on pectoral fins, D_1, D_2 and caudal fin; groung color of D_1 and D_2 pale gray; dorsal origin to ventral tip of caudal fin margin black; numerous small black spots form curved lines on caudal fin.

Ground color of preserved specimens:

darker than freshly dead specimen, though black spots much reduced on head and trunk.

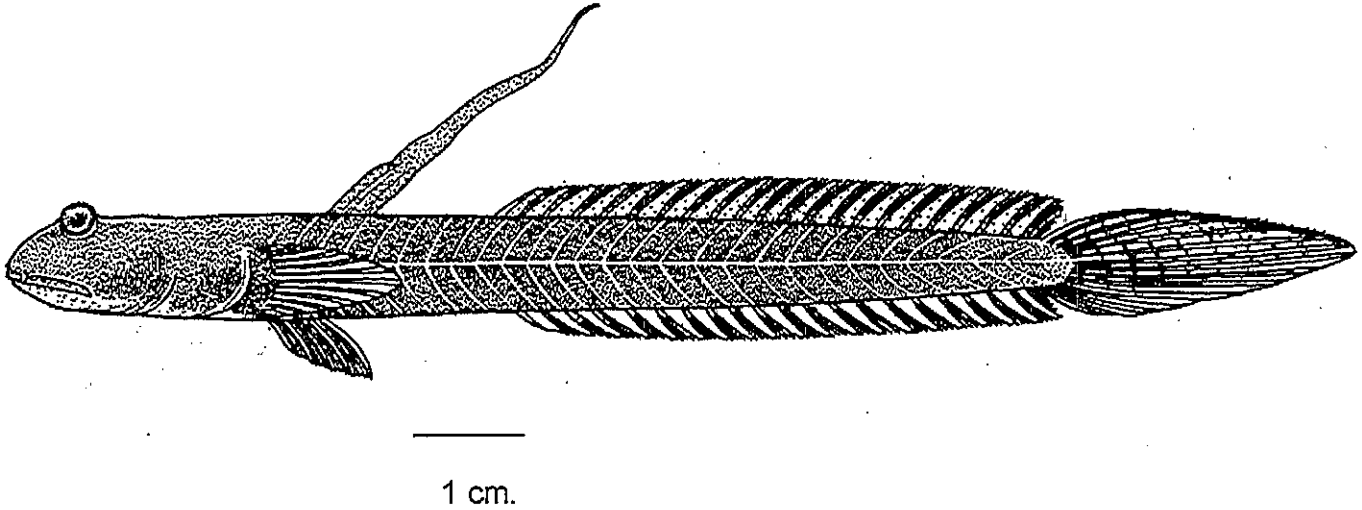

Fig. 13- *Scartelaos histophorus* (Valenciennes), 96.0 mm. SL.

3. Food Items Consumed by Mudskippers

The food items in the stomachs of mudskippers collected were investigated. Using relative importance index, each group of food items was ranked according to the percentage rate of occurrence. Food items from the whole stomach of each specimen were used to complete this procedure. Results are shown for the following sites: Laem-Hin, Pattani Bay, Ngao and La-Un. Each site had a different pattern of species combination or species coexistence, as shown by Horns' index of niche overlap

3.1 Relative Importance Index of Food Items Consumed by Mudskippers and Rates of Occurrence

The different species of mudskippers can be separated into three groups according to the food items found in their stomachs (see Table 3.1). The first group is strict herbivores. This group includes *B. boddarti*, for which every specimen examined contained benthic diatoms only. The main groups of benthic diatoms are *Pleurosigma* sp. and *Gyrosigma* sp. which are abundant on the exposed mudflat. However, other groups of benthic flora such as *Oscillatoria* sp., *Ceratium* sp., *Coconeis* sp. *Nitzchia* sp., *Navicula* sp., *Surirella* sp., *Diploneis* sp., and some nematodes can be found in *B. boddarti* as well.

The second group is omnivores. These include *S. histophorus*, which consumed both benthic diatoms and benthic harpacticoid copepods, while some also consumed unidentified small pelecypods.

The largest group of mudskippers are carnivores, feeding on several kinds of food such as crabs, insects, shrimps. Members of this group include *Pn. schlosseri*, *Ps.* cf. *novaeguineaensis*, *Ps. novemradiatus*, *Ps.* species A. and *Ps. chrysospilos.* Their main diets are crabs, which are consumed by all species in the group, and insects which are consumed by most of the species. Crabs consumed are mainly grapsid crabs (family Grapsidae) and to much lesser extent, some ocypodid juveniles. Insects which were found in the stomachs belong to order Hymenoptera and order Diptera.

The smaller carnivores including *Ps.* cf. *novaeguineaensis*, *Ps. novemradiatus*, *Ps.* species A and *Ps. chrysospilos,* consumed Hymenopteran insects more frequently than Dipteran insects, while the bigger carnivore: *Pn. schlosseri,* consumed Dipteran insects more frequently than Hymenopteran insects. Only the biggest-sized species, *Pn. schlosseri*, is able to feed on other unidentifiable small fish. Those found may have been juvenile gobies. There are three species which feed on pelecypods (possibly small tellinid bivalves): *Pn. schlosseri*, *Ps.* species A and *S. histophorus.* The first two species may have other strategies to find pelecypods in mud, but *S. histophorus* uses barbels to search for pelecypods, and even copepods, in small tidal pools. Unidentified shrimps (possibly belonging to families Alpheidae and Upogebiidae) are eaten by those species which forage at the tidal edge such as: *Pn. schlosseri*, *Ps.* cf. *novaeguineaensis*, *Ps.* species A, *Ps. argentilineatus* and *Ps. novemradiatus.* Alpheid and upogebiid shrimps are common burrow-dweller on mangrove floors.

The compiled values of the Relative Importance Index of the main food items of all species show the similar pattern as the percentage of occurrence of all species (Table 3.2). Although insects were eaten by big carnivorous species, such as *Pn. schlosseri* with a higher rate of occurrence, these were of less relative importance than other food items. Insects are in the third order in terms of percentage occurrence, to the fifth order in the relative importance in *Pn. schlosseri.* For the smaller carnivorous species - such as *Ps. chrysospilos*, *Ps.* cf. *novaeguineaensis* and *Ps. novemradiatus* - insects have a similar ranking in terms of both percentage occurrence and relative importance. *Ps.* cf. *novaeguineaensis*, however, consume small gastropods (*Assiminea brevicula*) more frequently than shrimps, but gastropods are a less important component of the overall diet according to Relative Importance

Index. The gastropods are in the fourth order in terms of percentage occurrence, but in the third order in the Relative Importance Index, while shrimps are in the fourth order in terms of percentage occurrence, but in the third order according to the Index of Relative Importance. *Assiminea brevicula* which is a tiny red gastropod is quite common on mangrove floor.

Some nematodes were found only in the stomach of *Pn. schlosseri* and *Ps.* species A. It is not known whether the nematodes were consumed for food or they happened to be parasitic nematodes. Khoo (1966) reported the incidents of nematode parasitism in the gut of *Pn. schlosseri.* Both *Pn. schlosseri* and *Ps.* species A forage at the tidal edge and may eat the nematodes by chance.

Although polychaetes are common in mangrove substrata, but they were found in the guts with low frequency and less relative importance by the small carnivore such as *Ps. argentilineatus*, *Ps.* cf. *novaeguineaensis* and *Ps. novemradiatus* which forage at the more exposed mudflat. *Onchidium*, which is a shell-less gastropod and common on mangrove floor, is consumed by *Ps.* cf. *novaeguineaensis*, *Ps. novemradiatus* and *Ps.* species A. Even *Onchidium* has low frequency values as a food item for the above mentioned species, but *Onchidium* becomes more important in terms of Relative Importance Index.

Benthic diatoms and copepods occurred in the stomachs of *S. histophorus* equally, but Relative Importance Index values for benthic diatoms were about 6.75 times higher than for copepods.

Table 3.1 Food Items and Percentage of Occurrence of Each Item in Ten Species of Mudskippers.

Occurrence(%)	Benthic diatoms	Crabs	Fishes	Gastropods	Insects	Copepods	Nematode	Onchidium	Pelecypods	Polychaetes	Shrimps
B. boddarti (n=170)	100.00	-	-	-	-	-	-	-	-	-	-
Pn. schlosseri (n=26)	-	46.15	3.85	-	7.69	-	7.69	-	11.54	-	7.69
Pn. septemradiatus (n=3)	-	100.00	-	-	33.33	-	-	-	-	-	-
Ps. argentilineatus (n=22)	-	54.54	-	13.63	31.81	-	-	-	-	4.54	13.63
Ps. chrysospilos (n=42)	-	9.52	-	4.76	26.19	-	-	-	-	-	-
Ps. gracilis (n=3)	-	100.00	-	-	-	-	-	-	-	-	-
Ps. cf. *novaeguineaensis* (n=159)	-	31.44	-	9.43	17.61	-	-	0.62	-	5.03	10.69
Ps. novemradiatus (n=368)-	-	50.00	-	11.95	16.3	-	-	0.81	-	4.89	5.16
Ps. species A (n=31)	-	22.58	-	-	4.23	-	19.35	6.45	6.45	-	9.68
S. histophorus (n=36)	100.00	-	-	-	-	100.00	-	-	22.22	-	-

Table 3.2 Relative importance Index for Food Items Eaten by Species of Mudskippers.

George & Hadley' index	Benthic diatoms	Crabs	Fishes	Gastropods	Insects	Copepods	Nematode	Onchidium	Pelecypods	Polychaeta	Shrimps
B. boddarti (n=170)	100.00	-	-	-	-	-	-	-	-	-	-
Pn. schlosseri (n=26),	-	58.78	2.7	-	5.22	-	15.32	-	7.61	-	10.38
Pn. septemradiatus (n=3),	-	71.42	-	-	28.67	-	-	-	-	-	-
Ps. argentilineatus (n=22),	-	46.4	-	16.88	21.19	-		-	-	5.05	10.46
Ps. chrysospilos (n=42),	-	10.89	-	23.12	65.99	-	-	-	-	-	-
Ps. gracilis (n=3),	-	100.00	-	-	-	-	-	-	-	-	-
Ps. cf. *novaeguineaensis* (n=159)	-	42.99	-	16.4	19.28	-	-	3.09	-	5.24	12.98
Ps. novemradiatus (n=368),	-	44.65	-	17.33	20.02	-	-	1.98	-	7.82	8.37
Ps. species A (n=31),	-	35.2	-	-	2.49	-	21	19.6	14.52	-	7.18
S. histophorus (n=36) ,	87.11	-	-	-	-	12.89	-	-	2.58	-	-

3.2 Food niche overlaps in terms of different coexisting species.

At different localities, different species of mudskippers can coexist. Four main patterns of more than two species of mudskippers that coexisted in one place were identified as shown in Table 3.3

Table 3.3 Combination of mudskipper coexisting species (more than two species) observed at four different localities.

Locality	Species combination
Pattani Bay	*B. boddarti* *Pn. schlosseri* *Ps. novemradiatus*
Laem Hin, Phuket	*S. histophorus* *B. boddarti* *Ps. chrysospilos* *Ps. novemradiatus*
La-Un, Ranong	*B. boddarti* *Ps.* species A *Ps. argentilineatus* *Ps. novemradiatus* *Ps.* cf. *novaeguineaensis* *Pn. septemradiatus*
Ngao, Ranong	*B. boddarti* *Ps.* species A *Ps. novemradiatus* *Ps. gracilis*

3.2.1 Laem Hin Combination:

Four species were found to be coexisting: *B. boddarti, Ps. chrysospilos, Ps. novemradiatus,* and *S. histophorus.* According to the food niche overlap calculations (Table 3.4), two pairs of mudskippers were likely to compete. Although the food niche overlap between *Ps. chrysospilos* and *Ps. novemradiatus* is high (0.843), according to my observations they tried to avoid competition. During the high tide period when water still covers the area, both species stay at the mangrove edge and show no feeding activity. During low tide, *Ps. chrysospilos* would follow the receding tide and gliding along the mud bank or shore to feed. During the incoming tide they would come back to same place, sometimes staying by clinging to mangrove roots or wood posts. *Ps. novemradiatus* which lives in similar areas would also remain in the same place and continue to forage.

Table 3.4 Horns' Index of Food Niche Overlap of Coexisting Mudskippers at Laem Hin Station.

Species	*B. boddarti*	*Ps. chrysospilos*	*Ps.novemradiatus*	*S.histophorus,*
B.boddarti (n=35)	1.00	0.00	0.00	0.608
Ps.chrysospilos (n=28)		1.00	0.843	0.00
Ps.novemradiatus (n=45)			1.00	0.00
S.histophorus (n=25)				1.00

The food niche overlap index between *B. boddarti* and *S. histophorus* does not show a strong overlap. Although they forage in the same area, fighting between the two species was hardly ever seen, while there were more intense fighting between members of the same species. Moreover benthic diatoms are abundant on the mangrove floor and the main diet of *S. histophorus* is small copepods.

3.2.2 Pattani Bay Combination:

The three coexisting species of mudskipper in this location are: *B. boddarti, Ps. novemradiatus, Pn. schlosseri.* *B. boddarti* had no problem in competing with the other species since they consume entirely different food resources. The amount of food niche overlap between *Ps. schlosseri* and *Ps. novemradiatus* is not high because they consume different food resources. *Pn. schlosseri* preys on fish, while approximately 50% of the gut content of *Ps. novemradiatus* was insects. *Pn. schlosseri* is much larger than *Ps. novemradiatus* - about ten times as big, in fact. *Pn. schlosseri* lives in exposed mudflats and along stream edges in front of mangroves, whereas *Ps. novemradiatus* lives in mangroves and forages there, among the roots. (See Table 3.5)

Table 3.5 Horn's Index of Food Niche Overlap of Coexisting Mudskippers at Pattani Bay Station.

Species	*B.boddarti*	*Pn.schlosseri*	*Ps.novemradiatus*
B.boddarti (n=52)	1.00	0.00	0.00
Pn.schlosseri (n=18)		1.00	0.095
Ps.novemradiatus (n=10)			1.00

3.2.3 La-Un Combination:

The six species, living in the same area at La-Un are: *B.boddarti, Ps. argentilineatus, Ps. novemradiatus, Ps.* cf. *novaeguineaensis, Ps.*species A and *Ps. septemradiatus. B. boddarti*, which is a strict herbivore, needs not to compete for food resources with other species. *B. boddarti* slides over the mud surface, browsing for benthic diatoms associated with sediment grains. The remaining species are carnivores. *Ps.* species A and *Ps. septemradiatus* were difficult to find in this area (only three specimens of each were found here). The reason why their population density was low, is not known. It might be due to competition, predation, or other factors.

The three species including *Ps. argentilineatus*, *Ps.novemradiatus* and *Ps. novaeguineaensis* should, in theory have problems in that they compete for the same food resources. Niche overlap indices for each pair combination are high, indicating their relatively similar food requirements (Table 3.6)

Table 3.6 Horn's Index of Food Niche Overlap for Coexisting Mudskippers at La-Un Station

Species	*B. boddarti*	*Ps. argentilineatus*	*Ps. noveaguineaensis*	*Ps. novemradiatus*	*Ps. species A*	*Pn. septemradiatus*
B. boddarti (n=12)	1.00	0.00	0.00	0.00	0.00	0.00
Ps. argentilineatus (n=22)		1.00	0.993	0.971	no data	0.843
Ps. noveaguineaensis (n=159)			1.00	0.965	no data	0.773
Ps. novemradiatus (n=83)				1.00	no data	0.832
Ps. species A (n=3)					1.00	no data
Pn. septemradiatus (n=3)						1.00

3.2.4 Ngao Combination:

Four species coexisting in the mangrove area at Ngao are: *B. boddarti, Ps. novemradiatus, Ps. species* A and Ps. *gracilis.* The indices of food niche overlap between *Ps.* species A and *Ps. novemradiatus*, and between *Ps.* species A and *Ps. gracilis*, are low. *Ps.species A* is larger than the other two species (twice as big). *Ps.species A* lives in burrows and moves from burrows to forage in more exposed areas during high tide or at night. The food niche overlap between *Ps. novemradiatus* and *Ps. gracilis* is moderate (Table 3.7). Unfortunately, only three specimens of *Ps. gracilis* were obtained and all of their guts contained only small crabs. *Ps. novemradiatus* consumed more varieties of food such as crabs, gastropods, *Onchidium*, and bivalves.

Table 3.7 Horn's Index of Food Niche Overlap for Coexisting Mudskippers at Ngao Station.

Species	*B.boddarti*	*Ps. gracilis*	*Ps. novemradiatus*	*Ps. species A*
B.boddarti (n=15)	1.00	0.00	0.00	0.00
Ps. gracilis (n=3)		1.00	0.688	0.351
Ps.novemradiatus (n=63)			1.00	0.375
Ps. species A (n=18)				1.00

The food items on which carnivorous species of mudskippers fed are not much different among the different habitats. The main food items of *Ps. novemradiatus* are still crabs and insects in every locality, but the minor food items are not similar. For example: polychaetes were never found in *Ps. novemradiatus* at Laem Hin, but they were found in the stomach of *Ps. novemradiatus* at Ngao and La-Un. Moreover the prey sizes may differ, depending on the size of predatory fish. *Pn. schlosseri* can consume crabs with the carapace length of 29.6 mm, while the smaller *Ps. novemradiatus, Ps. chrysospilos and Ps.* cf. *novaeguineaensis* are able to swallow crabs with the carapace length in the range of 1.85-3.85 mm. Herbivorous species also fed on different groups of benthic diatoms. Different species of benthic diatoms were found in their stomachs of herbivorous mudskippers living in both the same and different habitats.

4. Habitat use and other ecological information concerning mudskippers

Three study sites: Laem Hin (Phuket), Pattani Bay (Pattani) and La-Un (Ranong) were observed over 3 tidal cycles.

4.1 Laem Hin location

Laem Hin is a semi-enclosed estuary, located opposite Ko Ma Phrao (Ma Phrao Island). A rocky shore is connected to a small hill. This intertidal rocky zone is about 10-30 meters wide, almost flat and usually covered at high tide. At low tide there are many small tidepools. Close by is a muddy-sand shore. There are also mangrove plants here. Major mangrove species present include *Rhizophora apiculata* and *Avicennia marina.* Mangrove plants, in some places, are close to the rocky shore. This mangrove zone is about 20-50 meters wide and flooded by all medium high tides. The muddy zone is at the outermost part of Laem Hin Station, and it extends over 200-300 meters. This zone is the widest, softest and most closely connected to the water. Four species of mudskippers including *Boleophthalmus boddarti, Periophthalmus chrysospilos, Ps. novemradiatus,* and *Scartelaos histophorus,* were found at Laem Hin. Their ecological information is described below.

4.1.1 *Boleophthalmus boddarti*

Adults of *B. boddarti* live in muddy zones, but juveniles occupy muddy- sand areas. Fish forage during daytime when their habitat is nearly exposed or exposed to the air. The intensity of grazing, when the fishes' habitat has just been exposed to the air or when it is partially flooded, is high. Other activities also occur during this grazing period. Activities such as inter- and intraspecific aggression and courtship, increase with decreasing feeding activity. However, behavior aimed at prevention of desiccation is dependent on other factors including air temperature and air humidity changes.

B. boddarti rarely, however, forages at night. The reasons for this are not understood. One of the possible explanations is that most predators are more active and more abundant in the daytime. Fish move when the tide is high and begins to flood their habitat. Some of them go into burrows as soon as the tide floods their habitats, while others continue grazing. When the tidal level is too high for grazing, fish dive down to their burrows and stay there until the habitat is exposed to the air again. It is not known whether fish go back to the same burrows or not.

In order to graze on benthic diatoms, fish use both their pectoral fins as 'legs' to hold the body in a sTable position. The lower part of the mouth with its horizontal teeth on the lower jaw and membrane at the opening have been well evolved for grazing on mud surfaces. The head is moved from side to side. The fish continue to move to other areas and graze these for between three and five times. Grazed materials are kept in the mouth cavity. until the fish stop grazing. When these materials nearly fill the mouth cavity, the fish retain the benthic diatoms and blow out the rest. Fish do not choose whether this patch used to be grazed or not.

Intraspecific aggression is much more frequent than interspecific aggression. Fish expand the first dorsal fin, open the mouth, showing teeth and, sigmoidally, curve the body to signal hostility to an intruder. Most intraspecific aggression is followed by fighting which can sometimes take a long time to resolve. Fish bite each other's mouths and also collide head-to-head, dorsal fins extended, during fights. Although fighting of this nature and, particularly, biting looks quite serious, it may not be so. In my observation repelled fish were able to fight back again or go on to fight with other fish.

Interspecific aggression can take a similar form to intraspecific aggression but fighting rarely occurs and is usually not serious. Fish simply extend their dorsal fins and attack intruders by biting them two or three times. Intruders usually quickly leave the fish's territory rapidly and the fighting ceases.

In threatening situations, fish either move to stay close to their burrows (may or may not be their own burrows), or completely retreat into a burrow, though keeping predators in sight all the time. If a fish is seriously threatened it may retreat to its burrow suddenly. In general, fish enter their burrows head- or tail-first, though when they are threatened they always enter head-first.

The burrow of *B. boddarti* is the most complex among the mudskipper species. It is about 20-50 centimetres deep and there are many branches which U-turn and end up close to the surface. This is the stratege which fish uses to escape from predators. Fish enter the burrow opening and then randomly hide in any of the branches of the burrow. This means that predators must spend more time and energy in finding them. If a predator finds where the fish is hiding, it can still escape by wriggling up to the surface (see arrows) and skimming far away. The mechanism by which the fish build burrows is, however, not well understood. *B. boddarti* in the process of constructing its burrow was never observed.

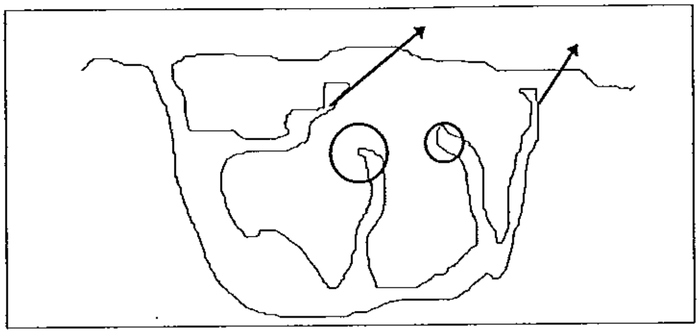

Fig. 14 Vertical section of the burrow of *B. boddarti* (not to scale), in the circles are the pockets for refuge and the solid arrows are the possible ways which fish escape by wriggling up to the surface.

4.1.2 *Periophthalmus chrysospilos*

The habitat of this fish varies widely. During high tide, fish are present in rocky zones. They attach themselves to available hard substrates such as: plant roots, stems, poles or rocks. Most fish allow only their head to emerge from the water, though some come out of the water completely. Foraging activity is very rare during this period. Fish forage by following the tidal level along the shore. Although fish form themselves into groups, The cooperative activity was never observed. In fact, the behavior of prey hunting as the fish follow the tide appears to be competitive. When the leading fish stops walking to eat its prey, the others continue to move ahead. Then the first, feeding fish must go rapidly, after it has finished its prey, to keep up with the group. Fish try to follow their own paths and to be the first or leading one in the group. Some fish, however, go alone and can find prey as effectively as those belonging to a group. Fish use two methods when consuming their prey:

4.1.2.1 Fish take mud in their mouths, retaining the prey and blowing out the rest. This method is not very common.

4.1.2.2 Fish approach their prey directly, then curve their body sigmoidally. When prey try to escape, fish attack them rapidly.

Aggression usually occurs when two fish locate the same prey. The first may directly attack prey, then, while it is trying to swallow it, the fish extends its dorsal fin to threaten others. If the prey is too large to swallow, another is likely to compete for it. Once one fish manages to swallow the prey, the competition ends.

During high tide, fish escape from predators by moving to other substrata if they are threatened. Some dive down to ground level, either retaining one position or moving. In the low tide period, fish tend to stay close to the river, or waterway. When pursued, fish may either skim far away on the shore, or float in the river, keeping their predators in sight. If they are still pursued, the group will break up. Members either dive down or swim further away. However, the group will ultimately form again. If fish stray far from the river on mud flats, they will tend to move rapidly to small tidepool and will submerge themselves in soft mud when they are pursued.

4.1.3 *Scartelaos histophorus*

This species inhabits damp mud in areas similar to *B. boddarti.* Feeding usually takes place during low tide in the daytime, though it may feed at any time during low tide. It is often possible to observe some fish feeding while others are resting or burrowing. The defensive behavior of this species - submerging the body in soft mud or in small tidepools - is different from that of *B. boddarti.*

Interspecific aggression is very rare and rarely serious, even though *P. chrysospilos* and *B. boddarti* forage in the same habitat. This species may find prey using the barbels on its lower jaw to detect the type of prey and its position. It will then take a large mouthful, including the prey and surrounding materials, retain the prey and blow the unwanted materials out.

In a threatening situation, fish either get into a burrow or stay close to them. Predators are kept in sight at all times. If a fish outside a burrow is increasingly threatened, it will go into the burrow rapidly. The fish will always enter the burrow head-first. Sometimes fish appear to deceive predators by appearing as though they have entered the burrow when, in fact, they just remain close to it.

4.1.4 *Periophthalmus novemradiatus*

This species lives on rocky shores among plant roots. During high tide, fish occupy the same habitat as *Ps. chrysospilos*. Competition, however, has not been observed between *Ps. novemradiatus* and *Ps. chrysospilos,* because *P.novemradiatus* usually lives above the water line, while *Ps. chrysospilos* live in the shallows, moving higher as the tide advances. The body and tail of this species is usually submerged in water. During low tide fish stay in the same habitat and forage on the flat, or in small tidepools. Territorial behavior may occur, especially in big fish. The territorial size is unknown. When in its own habitat and not under threat, this fish has a normal color, but it becomes dark and expands its dorsal fin to deter aggressors, if they appear. The occupier of a territory tends to approach an intruder suddenly. However, fighting does not usually occur because the intruder leaves the territory, becoming paler in color. If an intruder cannot escape, it will be bitten. When a fish is in its own habitat and is faced by an intruder, it will itself become darker threatening aggression. *Ps. novemradiatus* will not usually try to escape from an intruder by leaving its own territory.

Foraging occurs during low tide. Fish stay close to small tide pools or around plant roots, changing color to mimic their surroundings. They creep slowly towards their prey, curving the body sigmoidally. When the prey is within attacking distance, it is rapidly attacked. However, prey species, prey size, prey behavior, and the size of the fish themselves, have an effect on predatory behavior.

4.2 Pattani Bay Location

This station comprises a very wide mudflat of approximately 400 meters wide. Some mangrove species have been planted in the last ten years. Although the mudflat is open to the sea, fresh water and inland sediment from the Pattani River play an important role. A very soft mud layer is about two meters thick. At low tide, most mudskippers' habitat is exposed to the air for a long period. There are many bird species, migratory birds and native birds, which forage on the swamp and shore edge during low tide. The habitat and ecological information concerning *Pn. schlosseri* are shown below:

4.2.1 *Periophthalmodon schlosseri*

This species inhabits open mudflats. During low tide, fish behave in a number of ways: some rest, either by lying on the mudflat or by immersing themselves in their own burrows; some mend their burrows, taking mud in their mouths and blowing it out around the burrow opening; some move to the burrows of other fish or seek prey.

This fish is very easily frightened. In threatening situations, when the fish is far from its burrow, it skims rapidly back to the burrow and then keeps close to, or enters the burrow. If it is more seriously threatened, it goes into its burrow and settles down until it feels free from the intruder. Then it carefully emerges again. If it is still threatened, the fish will return to the burrow and settle down for a longer period. Most fish will return to their own burrows in a threatening situation, though they will sometimes retreat to the nearest burrow even though it belongs to another fish.

During the start of the flood tide, when water floods their burrows, fish leave their burrows. They forage near the channel or river's edge. Although fishes forage in groups no fighting occurs between group members. Sometimes the fish will sit and wait for prey at the tidal edge, or they will move around in search of prey. After finishing food, the fish rests under shady plants and returns to its burrow at low tide. It is not clear whether fish return to their own burrows or not.

There are two strategies adopted by this species when escaping from enemies. Firstly, they can skim very fast along the water; or, secondly, dive down to the river or channel bed. When diving, fish either settle in the same position or move to other positions. It does not take much time to settle in a position on the channel bed.

When *Pn. schlosseri*'s burrow is examined, we usually saw that a number of small mudballs have been dropped around its burrow. The shape and depth of the burrows vary. Sometimes they have only a single turret with no branches; some are L-shaped; others have three rooms, the first about 50 cm deep. It has a flat floor, a curved roof, and about 30 cm of horizontal tube, providing an opening to the main turret. Further, about 100 cm deep, the main turret is divided into two branches. Each branch leads obliquely to a room. There are no other connections from room to room.

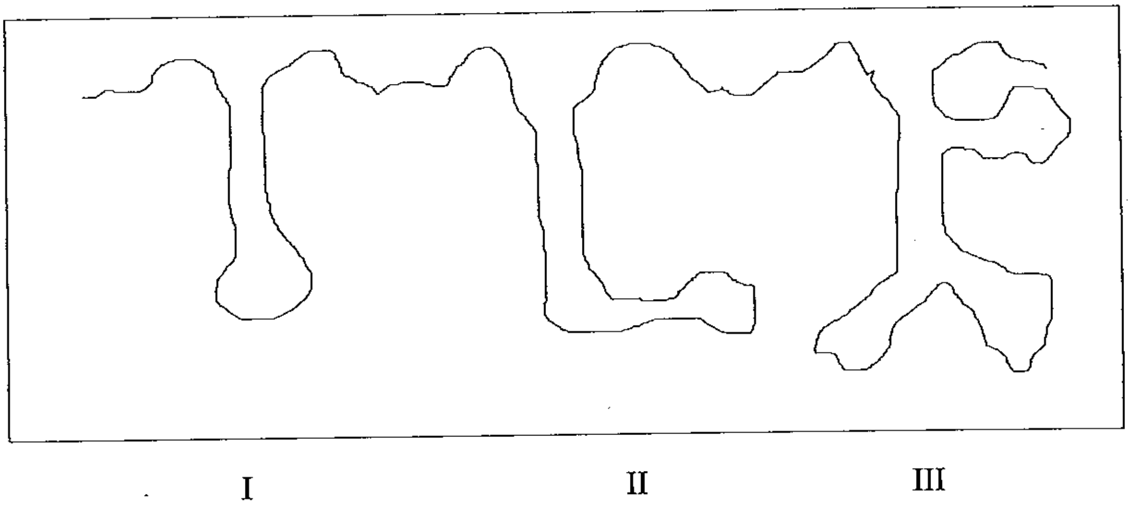

Fig. 15 Three types of burrow of *Pn. schlosseri*, found at Pattani Bay: the single turret type, L-shaped type, and branched-type. (not to scale)

4.3 La-Un location

This location is located on the Andaman coast and includes healthy mangroves and many shallow swamps The tidal range (of approximately 2-5 meters) is much wider than in the Gulf of Thailand. There are six species of mudskippers here: *Boleophthalmus boddarti, Ps. noveaguineaensis, Ps.* species A, *Ps. argentilineatus, Ps. novemradiatus and Pn. septemradiatus.*

Habitat use and ecological information about *Ps. novemradiatus* and *B. boddarti* are as previously described. Data for *Pn. septemradiatus* and *Ps. argentilineatus* are not reported because these species are very difficult to find and recognize.

4.3.1 *Ps.* cf. *novaeguineaensis*

This species lives in a wide range of habitats (abundant on river banks, rarely living in small swamps in the mangrove). Some of them occupy a burrow which was been lived in by other organisms, on the mangrove flats. The burrow is used as a shelter.

Foraging occurs at both low and high tides. There are several strategies for hunting prey. The first is by searching for prey individuals. The fish occupies an area, in which it expects prey may be present. Its color adapts to fit with the surroundings, it remains silent and then approaches its prey. If no prey are present, the fish will move to another area. Sometimes the other areas have already been occupied, and this can lead to aggression, or fighting. The outcome of fighting is usually determined by which fish initially occupied an area (if the fish sizes are equal), or if one fish is bigger it usually wins. Threatening behavior occurs both within and between species. These fish extend the first dorsal fin as they approach an opponent.

The frequency of feeding and handling time depends on the prey size and on the kind of prey consumed. Fish always eat their prey by breaking external limbs or organs, such as the legs of crabs or wings of insects, which give them no mobility. Then the fish tries to swallow the remainder of the prey whole. However, not all fish find prey during a single tidal period.

4.3.2 *Ps.* species A

This species lives in mangrove forests. They build burrows which are about 9-13 cm in diameter and 100-120 cm in depth. The burrows of the fish of this species sometimes look very similar to those of *Pn. schlosseri.* The fish create a turret by taking mud from the burrow in their mouths and blowing it out near the burrow opening. Both males and females create their own turrets, though they sometimes stay in the same burrow. These fish are nocturnal. They leave the burrow to feed in the evening and return in the morning. During daytime, fish hang on to the burrow turret or work on the burrow to make it deeper.

The general behaviors of the same species of mudskippers in different localities, however, did not differ. Mudskippers of particular species displayed the same behavioral patterns. The grazing behavior *of B. boddarti* on the Andaman Coast seemed to be more intense than members of the same species on the Gulf of Thailand Coast.

Chapter 4

Discussion

At least 10 species of mudskippers are present in south Thailand. They belong to four genera: *Boleophthalmus*; *Periophthalmus*; *Periophthalmodon*; and *Scartelaos*.

The single species in the genus *Boleophthalmus* is *Boleophthalmus boddarti*. The genus *Periophthalmus* is comprised of six species; *Periophthalmus argentilineatus; Ps. chrysospilos; Ps. gracilis; Ps.* cf. *novaeguineaensis; Ps; novemradiatus*; and *Ps.* species A (unnamed). Previous authors do not offer any description that fits this species (Murdy, 1989; Tomiyama, 1936; Smith, 1959). It has single row of teeth on the upper jaw. This is the most distinctive characteristic used in differentiating the genus *Periophthalmus* from the genus *Periophthalmodon*. Its pelvic fins are completely joined forming a disk, but Murdy (1989) recorded that the only species with joined pelvic fins forming a disk is *Ps. chrysospilos*. The *Ps.* species A, however, has many characteristics and color differences compared with *Ps. chrysospilos*. For example, the first dorsal fin of *Ps.* species A is curved while it is flag or triangular-shaped in *Ps. chrysospilos*; there are dark brown and pale yellow spots on the head and the trunk in *Ps.* species A but these are pale gray and dark yellow or orange spots on the trunk of *Ps. chrysospilos*.

There are two species in the genus *Periophthalmodon*: *Pn. schlosseri* and *Pn. septemradiatus*. The last genus is *Scartelaos* which contains a single species: *S. histophorus*.

The distribution surveys of mudskippers show that two species: *B. boddarti* and *Ps. novemradiatus* are common in southern Thailand. *Pn. schlosseri* is present only in the Gulf of Thailand, but *Ps. septemradiatus, Ps.* cf. *novaeguineaensis, Ps. gracilis* and *Ps.* species A are only present in the

Andaman Sea. *S. histophorus* appears on both coasts of southern Thailand. *Ps. argentilineatus*, *Ps.* cf. *novaeguineaensis* and *Ps. gracilis* were present only in Ranong province. *Ps. argentilineatus* and *Ps. gracilis* have also been reported in mangrove areas in Songkhla Lake. They were caught using a scoop net and set bag respectively (Sirimontaporn, 1993). They are also considered to be rare species. The possibility of migrations of mudskippers between habitats may be limited because mangrove areas of southern Thailand are separated by sandy beaches or rocky shores. However, a gene flow between populations may occur by dispersal during the larval stages. However the speciation rate is probably low, except in the case of *S. histophorus* (present in Chumporn and Phuket), which may differ from each other because they are separated from each other by the Isthmus of Kra.

Boleophthalmus is a strict herbivore, like *B. boddarti* (Koo, 1966; quoted in MacNae, 1968; Clayton, 1993). Only benthic diatoms were found in the stomachs of individuals of this species which were examined. This species is a non-selective grazer because the main groups of benthic diatoms are different in different individuals. It is possible that *B. boddarti* may be an omnivore, or a generalist during the pelagic phase of its life, becoming a strict herbivore when it settles on the mud bank. In 1969, Mutsaddi and Bal collected over 1000 specimens of *B. boddarti* from the Bombay coast at monthly intervals over the course of a year. Their results showed that fish ingested algae, diatoms, polychaetes, nematodes, crustaceans and teleost eggs. Monthly percentage occurrence values showed that crustaceans formed the dominant food of juvenile fish (total n for the whole year = 330, 16-95 mm SL, no gonadal development); while for adults (n = 680, 96-185 mm) plant materials, particularly diatoms, were dominant (quoted in Clayton 1993). In decreasing order of importance in the diet are the bacillariophytes: *Pleurosigma, Navicular, Nitzchia*, and *Synedra*; the chlorophyte, *Closteriopsis,* and the cyanophyte, *Oscillatoria* (Sarker *et al.*, 1980, quoted in Clayton, 1993)

Benthic diatoms and copepods were found in *S. histophorus'* intestines. It has been documented that *Scartelaos,* such as *S. viridis* [= *S. histophorus*], is omnivorous, feeding on both plant and animal materials. It consumes diatoms, *Oscillatoria* sp., *Pleurosigma* spp., *Niztchia* sp. and the cyanobacteria, *Lyngbya* sp. as the main plant material. Harpacticoid copepods, chromadoroid molluscs and nematodes are also consumed. (Koo, 1966, quoted in MacNae, 1968; Clayton, 1993) Animal material may be the main food of *S. histophorus.* However, as the data in Table 3.2 shows, the relative important index for animal material is only about eighteen percent of that of benthic diatoms. Because of the percentage of cover area of copepods which was applied as percent weight in Relative Importance equation may not be accurate. *S. histophorus* has barbels on the underside of its head. This organ may be useful for finding prey hidden in the mud. Carnivorous species (member of the genera *Periophthalmus* and *Periophthalmodon*) (Clayton, 1993) may be able to consume more varieties of food than those mentioned in Tables 3.1 and 3.2. It has been reported, for example, that *Pn. schlosseri* is completely carnivorous. *Ps. chrysospilos* also tends to be carnivores, but supplements its diet with plant materials. (Koo, 1966, quoted in MacNae 1968). Some nematodes are parasites of carnivores (Clayton, 1993). They were capsulized in mucus and appeared as cysts and were undigested in the digestive tract of carnivorous species. Koo (1966) found that larval ascarid nematodes infect the gut of *Pn. schlosseri* and cestodes, agamofilarial and acanthocephalid cysts have been found in *Ps. koelreuteri* (Pearse, 1993) = *Ps. barbarus* (Linnaeus), *Pn. schlosseri* and *B. boddarti* (Koo, 1966, quoted in Clayton, 1993). However, I found benthic diatoms in the digestive tract of carnivorous species as well. Indeed, close to the end of the digestive tract of every species I found undigested benthic diatoms. Carnivorous species may not gain much benefit from consuming benthic diatoms but they may feed on them for a change or they may accidentally ingest sediment containing diatoms.

The sizes of carnivorous species varied greatly. For example, *Pn. schlosseri* is about ten times larger than *Ps. novemradiatus* and *Ps.* species A is about twice as large *as Ps. novemradiatus, Ps. gracilis* and *Ps.* cf. *novaeguineaensis.* The larger species may consume prey of different sizes compared to the smaller species. *Pn. schlosseri*, in particular, forage during the incoming high tide at the stream edge, and consume a great variety of food. There are significant variations in the animal species present during different stages of the tidal flow. All the prey species living in *Ps. novemradiatus, Ps.* cf. *novaeguineaensis* and *Ps. argentilineatus* habitats are migratory and spawn at different times, so the density and composition of the prey species present in their habitats fluctuate all time (Mutsaddi and Bal, 1969a, quoted in Clayton 1993).

Predatory success is dependent on many factors such as: general behavior (for instance, the escape instinct), physical and chemical conditions in the locality, color, structure and size of prey. The structure and size of the predator's mouth play an important part in food selection. The older or bigger fish seem to be more successful in hunting prey than the younger, inexperienced fish. In studying the predatory behavior of trout, it was found that feeding times and reactive distance, (the distance from which the prey attract the fish), varied with the time that fish spent in contact with the prey (amount of experience) (Gerking, 1994).

All combinations of coexisting species showed some overlap of food consumption, particularly among the smaller carnivorous species*:* *Ps. novemradiatus, Ps. gracilis* and *Ps.* cf. *novaeguineaensis.* They partition food resources using many strategies. Observing territories is a part of mudskippers' specialized feeding strategies. Mudskippers' territory is non-contiguous. They frequently shift from one territory to another to enable themselves to gain the maximum net energy gain during the feeding period. The size and shape of the territory covered by individual fish depend on fish density (Clayton, 1987 and 1993). The purpose of defensive territorial behavior by small carnivorous mudskippers is for food-gathering space, though this does not apply in the cases *of B. boddarti* and *Pn. schlosseri. B. boddarti* seem to be highly defensive in their territorial behavior (MacNae, 1968; Clayton, 1982, 1987, 1988, and 1993) during the feeding period, but I observed that *B. boddarti* may not actually defend its feeding area. Defensive territorial behavior is not shown at the beginning of the feeding period by most members of this species. When the feeding rate is reduced, or almost stopped, *B. boddarti* begins to defend its territory. It is possible that the aim of this behavior is to protect its nesting and spawning grounds and, particularly, to present itself to the opposite sex. The occupier of a territory will repel some individual but not others.

Pn. schlosseri does not show territorial behavior during feeding periods either. It defends only the area of mud-wall at its burrow, and only against some individuals. Its burrow can be several different shapes, though the purpose of this is not quite clear. It may be due to factors such as breeding season, predation risk, etc.

Most mudskipper species - *B. boddarti, Ps. novemradiatus, Ps. gracilis, Ps.* cf. *novaeguineaensis, Ps. argentilineatus* and *S. histophorus* - forage during the daytime and hide in shelters or burrows at night, even though their prey is still abundant at this time. This behavior may be a result of the fact that at night, they are at greater risk of predation from many kinds of mangrove snakes. In the case of the herbivorous *B. boddarti*, this behavior may be a result of the fact that, at night, benthic diatoms have a lower nutritional and energy value than during the daytime. It is therefore more beneficial - for maximum net energy gain - for *B. boddarti* to forage during the daytime.

The values of Horns' index show that food niche overlap among certain species of mudskippers can be high. However, from the field observation over several long periods, the competition for food among those with high values of food niche overlap does not seem to be severe. This could be attributed to several speculations. They may forage in different places or feed at different times to avoid encounter. Different species may feed on the same kind of food, but they may capture different sizes of prey. And the last but not the least plausible explanation is that food resources in mangroves are abundant. Interspecific competition for food can be thus avoided.

Due to the field observation of the interaction among the members of the same species and different species (fighting, aggression, feeding, territoriality), the interspecific competition (competition among different species) is much less intense than the intraspecific competition (competition within the members of the same species). Individuals of the same species must compete for food, mating and burrows, while members of different species only compete for food. Many mudskippers, especially predatory species, are able to consume a variety of prey species. Thus they can perform prey-switching to avoid competition. Mudskippers also avoid interspecific competition by feeding at different times and in different places. However, the understanding about their food resource partitioning or seasonal variation of food sources consumed by mudskippers is lacking. Future research should involve long-term sampling to investigate the seasonal changes of food resource uses by mudskippers as well as the changes in food species composition and abundance. Detailed studies on behavioral patterns of different species and interaction are needed to get better understanding of the coexistence of mudskipper species.

Chapter 5

Conclusion

This study of the taxonomy and ecology of mudskippers (Gobiidae: Oxudercinae) in southern Thailand was carried out from October 1994 to October 1995. The conclusions are as follows:

1. Ten species of mudskippers are present in southern Thailand. They belong to 4 genera:

    1.1 *Boleophthalmus* which comprises a single species:
        Boleophthalmus boddarti (Pallas)
    1.2 *Periophthalmus* contains 6 species which are:
        Periophthalmus argentilineatus Valenciennes
        Periophthalmus chrysospilos Bleeker
        Periophthalmus gracilis Eggert
        Periophthalmus cf. *novaeguineaensis* Eggert
        Periophthalmus novemradiatus (Hamilton)
        Periophthalmus species A (unnamed)
    1.3 *Periophthalmodon* contains 2 species:
        Periophthalmodon schlosseri (Pallas)
        Periophthalmodon septemradiatus (Hamilton)
    1.4 *Scartelaos* which has a single species:
        Scartelaos histophorus (Valenciennes)

Three species are new records of Thailand, namely *Ps. chrysospilos*, *Ps.* cf. *novaeguineaensis* and *Ps.* species A (unnamed). *Ps.* species A may have been a new species belonging to the genus *Periophthalmus.* It has a single row of teeth on the upper jaw and pelvic fin united into disk. Although these two characteristics are very similar to those of *Ps. chrysospilos*, other morphological measurements, counts, coloration and general behavior are different from those of *Ps. chrysospilos*.

The following seven species of mudskippers: *B. boddarti, Pn. septemradiatus, Ps. argentilineatus, Ps. chrysospilos, Ps. gracilis, Ps.* cf. *novaeguineaensis, Ps. novemradiatus, Ps.* species A, and *S. histophorus* are present on the west coast of Thailand or in the Andaman coastal waters. Five of which (*Pn. septemradiatus Ps. argentilineatus, Ps.* cf. *novaeguineaensis,* and *Ps.* species A) are confined only to the west coast. Six species, which are *B. boddarti, Pn. schlosseri, Ps. chrysospilos, Ps. gracilis, Ps. novemradiatus* and *S. histophorus*, can be found in the Gulf of Thailand. Only *Pn. schlosseri* is found to be present in the Gulf of Thailand, (it has never been found on the west coast).

2. There are herbivorous, carnivorous and omnivorous mudskippers. *B. boddarti* is a strict herbivore, feeding only on benthic diatoms, mainly on *Pleurosigma* sp., *Gyrosigma* sp., *Nitzchia* sp., and *Navicula* sp.

Members of the genus *Periophthalmus* and the genus *Periophthalmodon* are carnivorous. Their main food items are crabs (grapsid crabs), and hymenopteran and dipteran insects. The lesser important groups are tiny red gastropods (*Assiminea brevicula*), Upogebiid and alpheid shrimps (unidentifiable) and polychaetes (unidentifiable). The carnivorous mudskippers may, by chance, ingest benthic flora into their guts. It is not known whether they can benefit from benthic diatoms as food.

The last group is an omnivorous species, *S. histophorus*, feeding on benthic diatoms, small harpacticoid copepods and juvenile tellinid bivalves.

3. Some mudskippers can coexist, because they utilize different food resources or different prey sizes. Mudskippers of different species with similar food requirements (high food niche-overlap) may be able to coexist, because they forage in different places, feed at different time, are able to

switch prey for consumption. Another plausible explanation is that mangroves provide sufficient food resources for mudskippers, thus the competition for food is not intense.

4. From field observations of feeding behavior and inter- and intraspecific competitive behavior (or aggressive behavior), it can be concluded as follows:

4.1 Carnivorous mudskippers have different strategies for finding (or hunting) prey. *Ps. novemradiatus* and *Ps.* cf. *novaeguineaensis* mostly perform sit and wait, prior to prey capturing, but occasionally they move to search for preys. *Pn. schlosseri* , *Ps.* species A, and *Ps. chrysospilos* go out of their burrows or resting sites, to forage or hunt for the incoming prey at the tidal edge.

4.2 Herbivorous mudskippers graze on benthic diatoms by using the horizontal teeth and the folded-lips. Benthic diatoms will be sorted out and retained from the taken materials, then swallowed into the gut while the rest will get blown out.

4.3 Omnivorous mudskippers use barbels as the prey-detecting organ, searching the hidden preys. Sometimes, they go to drier areas and graze on benthic diatoms.

5. Mudskippers of different species can coexist in the same mangrove habitats. The interspecific (between different species) competitive behavior (such as threat display, fighting) has been less frequently observed. On the contrary, intraspecific competitive behavior has been frequently among members of the same species .

The intraspecific competitive behavior, especially in *B. boddarti*, occurs very commonly for the propose of territory defense (may be for nesting sites, mating, and even for the feeding ground).

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Glossary

anteriordorsal	the position or area located at the upper part of the frontage of any appendage.
basal	the position or area which mostly located at the base of any appendage.
barbels	the small of soft warts arranged in two rows on under side of head and the biggest one is at the lower jaw symphysis
dorso-lateral	the position or area which mostly located at the upper part of the side of any appendage.
dorso-marginal	the position or area located at the upper margin of any appendage.
dorso-posterior	the position or area which mostly located at the upper part of the back of any appendage.
frenum	a fold of skin unites the upper part of pelvic fins
inframarginal	the position or area located close to the inner side of margin of any appendage.
interorbital	the position or area located between the protrusive eyes.
latero-ventral	the position or area which mostly located at the lower part of the side of any appendage.
mesial	the position or area located at the middle part of any appendage.

posteriorventer	the position or area which mostly located at the back of the under part of appendage.
ray	the fin supporter of first dorsal fin
ray (branched ray)	the fin supporter of second dorsal fin. (except the first fin supporter)
ray (segmented ray)	the first fin supporter of second dorsal fin
trunk	the body of fish
venter	the under part of body
ventro-posterior	the position or area which mostly located at the lower of the back part of appendage.
ventro-lateral	the position or area which mostly located at the lower part of the side of any appendage.

Appendix

Table 1. Ranges, means and standard deviations of measurements of body depth and head length expressed as a percentage of standard length.

Species	Body depth				Head length			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	15.4	18.1	13.0	1.06	26.5	29.4	14.2	2.28
Pn. schlosseri	15.1	16.1	14.2	0.56	28.0	29.7	26.3	0.95
Pn. septomradiatus	15.1	15.4	14.4	0.57	25.9	26.2	25.5	0.36
Ps. argentilineatus	13.4	17.5	11.8	1.20	25.2	30.3	23.6	1.53
Ps. chrysospilos	14.5	20.0	12.0	1.59	24.7	26.7	22.7	0.94
Ps. gracilis	12.0	12.8	10.7	0.97	23.1	23.7	22.6	0.50
Ps. cf. *novaeguineaensis*	13.3	15.1	12.1	0.74	24.1	25.7	23.1	0.64
Ps. novemradiatus	14.1	19.1	11.8	1.06	24.3	26.4	17.3	1.34
Ps. species A	14.1	15.0	12.7	0.72	26.8	28.5	25.3	1.00
S. histophorus	8.0	10.2	6.7	1.01	17.8	21.5	14.8	1.96

Table 2. Ranges, means and standard deviations of measurements of head depth and head width expressed as a percentage of standard length.

Species	Head depth				Head width			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	16.0	18.9	11.5	1.01	16.3	18.7	13.5	1.08
Pn. schlosseri	18.1	19.7	16.2	0.86	18.4	22.4	15.0	1.95
Pn. septomradiatus	18.9	19.7	17.7	1.11	18.1	18.9	16.6	1.32
Ps. argentilineatus	16.9	18.4	14.4	0.88	16.5	17.7	14.7	0.96
Ps. chrysospilos	14.5	16.3	12.4	0.93	15.5	18.4	14.1	1.10
Ps. gracilis	13.7	14.3	13.1	0.54	16.2	17.5	15.0	1.06
Ps. cf. *novaeguineaensis*	16.1	16.7	15.5	0.34	15.9	17.3	10.0	1.87
Ps. novemradiatus	16.7	19.1	1.8	2.61	17.3	22.7	13.8	1.22
Ps. species A	19.5	21.1	17.8	0.93	20.9	23.0	18.5	1.24
S. histophorus	8.6	10.2	7.6	0.76	9.6	12.2	8.2	1.22

Table 3. Ranges, means and standard deviations of measurements of heigth of pectoral fin base and first dorsal fin base length expressed as a percentage of standard length.

Species	Heigth of pectoral fin base				First dorsal fin base length			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	9.8	12.7	4.3	1.42	8.9	15.2	4.3	1.80
Pn. schlosseri	12.8	14.5	10.7	1.06	13.3	17.2	7.4	2.68
Pn. septomradiatus	11.9	13.2	10.5	1.34	10.2	17.5	0.0	9.21
Ps. argentilineatus	10.5	18.7	9.3	2.16	16.9	19.6	13.6	1.61
Ps. chrysospilos	10.3	11.5	8.9	0.84	10.5	16.7	5.4	3.15
Ps. gracilis	8.9	9.3	8.4	0.43	19.3	20.4	17.7	1.18
Ps. cf. *novaeguineaensis*	10.2	11.3	9.0	0.69	17.7	21.9	9.8	2.89
Ps. novemradiatus	10.8	25.3	8.9	2.29	17.1	23.1	11.0	2.78
Ps. species A	11.5	12.9	10.4	0.64	14.9	17.5	10.1	2.21
S. histophorus	4.9	6.2	4.3	0.52	3.9	5.5	2.8	0.77

Table 4. Ranges, means and standard deviations of measurements of second dorsal fin base length anal fin base length expressed as a percentage of standard length.

Species	Second dorsal fin base length				Anal fin base length			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	39.2	42.5	33.4	1.42	36.8	40.4	34.0	1.26
Pn. schlosseri	21.4	28.3	18.5	2.19	20.5	23.2	18.0	1.11
Pn. septomradiatus	21.1	23.5	18.9	2.30	14.8	15.9	13.9	1.02
Ps. argentilineatus	21.1	23.6	19.1	1.16	18.9	20.2	17.2	0.82
Ps. chrysospilos	20.4	23.9	17.5	1.48	18.2	20.9	14.7	1.48
Ps. gracilis	19.3	20.4	17.7	1.18	17.9	19.1	16.2	1.28
Ps. cf. *novaeguineaensis*	21.8	23.1	19.5	0.82	21.0	22.6	18.8	1.09
Ps. novemradiatus	21.6	25.6	18.4	1.42	18.6	25.9	15.9	1.73
Ps. species A	17.7	21.9	14.5	2.17	14.9	15.8	14.1	0.44
S. histophorus	41.3	49.9	37.9	3.44	37.7	45.6	34.0	3.23

Table 5. **Ranges, means and standard deviations of measurements of caudal fin length and pectoral fin length expressed as a percentage of standard length.**

Species	Caudal fin length				Pectoral fin length			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	17.7	24.5	8.6	4.04	17.6	22.2	11.0	2.62
Pn. schlosseri	14.9	18.6	12.8	1.30	24.1	26.6	20.7	1.45
Pn. septomradiatus	14.5	15.4	13.1	1.24	22.4	23.0	22.0	0.51
Ps. argentilineatus	18.6	20.2	17.1	0.87	22.7	25.2	20.1	1.35
Ps. chrysospilos	20.9	24.3	10.7	3.42	23.2	27.3	18.6	2.00
Ps. gracilis	19.6	20.2	18.9	0.56	21.4	22.7	20.2	1.10
Ps. cf. *novaeguineaensis*	18.6	21.3	17.0	1.03	22.7	25.6	20.3	1.48
Ps. novemradiatus	18.6	25.6	7.0	2.48	22.7	25.9	7.6	2.18
Ps. species A	14.2	16.5	12.5	1.20	22.7	26.6	13.4	3.74
S. histophorus	19.2	23.1	17.6	1.89	10.7	13.4	9.0	1.32

Table 6. **Ranges, means and standard deviations of measurements of pelvic fin length and body depth at least depth of caudal peduncle expressed as a percentage of standard length.**

Species	Pelvic fin length				Body depth at least depth of caudal peduncle			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	14.0	22.5	6.6	2.10	8.3	16.3	6.6	1.19
Pn. schlosseri	14.6	16.4	13.2	0.77	9.6	10.4	8.7	0.51
Pn. septomradiatus	13.3	13.9	12.5	0.70	8.1	8.8	7.3	0.76
Ps. argentilineatus	12.3	23.0	10.2	3.28	7.3	7.8	6.6	0.34
Ps. chrysospilos	13.1	15.5	10.3	1.10	7.9	8.5	7.3	0.34
Ps. gracilis	11.0	11.8	10.4	0.63	7.0	7.5	6.6	0.40
Ps. cf. *novaeguineaensis*	9.9	11.1	8.9	0.61	7.4	8.0	6.7	0.39
Ps. novemradiatus	11.8	17.7	10.6	1.00	7.8	19.2	0.7	2.38
Ps. species A	13.0	14.2	11.6	0.65	8.2	8.8	7.4	0.49
S. histophorus	9.7	11.2	8.2	0.98	4.6	5.7	3.9	0.53

Table 7. **Ranges, means and standard deviations of counts of pectoral fin rays.**

Species	Pectoral fin rays (left side)				Pectoral fin rays (right side)			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	18.36	21.00	17.00	0.91	18.63	21.00	17.00	0.93
Pn. schlosseri	14.81	18.00	12.00	1.28	14.05	17.00	12.00	1.11
Pn. septomradiatus	13.67	14.00	13.00	0.58	13.00	13.00	13.00	0.00
Ps. argentilineatus	11.00	12.00	10.00	0.71	10.88	12.00	10.00	0.70
Ps. chrysospilos	13.92	15.00	13.00	0.76	14.08	15.00	12.00	0.95
Ps. gracilis	11.33	13.00	10.00	1.00	11.22	12.00	10.00	0.97
Ps. cf. *novaeguineaensis*	12.31	16.00	10.00	1.49	12.31	15.00	11.00	1.14
Ps. novemradiatus	10.89	13.00	9.00	0.89	10.90	13.00	9.00	1.14
Ps. species A	13.71	15.00	12.00	1.03	14.00	15.00	13.00	0.53
S. histophorus	18.00	19.00	17.00	0.82	18.33	19.00	18.00	0.47

Table 8. **Ranges, means and standard deviations of counts of longitudinal scales and transverse scales.**

Species	Longitudinal scales				Transverse scales			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	79.2	106.0	67.0	8.28	19.9	33.0	15.0	3.27
Pn. schlosseri	51.7	62.0	53.0	2.22	14.0	20.0	12.0	1.93
Pn. septomradiatus	57.7	59.0	56.0	1.53	17.3	23.0	14.0	4.93
Ps. argentilineatus	66.1	76.0	57.0	5.42	15.4	18.0	13.0	1.32
Ps. chrysospilos	72.8	82.0	64.0	5.99	18.5	21.0	17.0	1.19
Ps. gracilis	61.1	70.0	52.0	6.97	15.3	19.0	13.0	1.80
Ps. cf. *novaeguineaensis*	78.5	88.0	69.0	5.56	17.8	20.0	16.0	1.25
Ps. novemradiatus	64.3	75.0	55.0	4.29	15.7	19.0	13.0	1.52
Ps. species A	64.0	71.0	61.0	3.38	13.9	15.0	12.0	0.99
S. histophorus								

Table 9. Ranges, means and standard deviations of counts of predorsal scales and spinous dorsal fin rays.

Species	Predorsal scales				Spinous dorsal fin rays			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	32.0	44.0	25.0	4.06	5.0	5.0	5.0	0.00
Pn. schlosseri	21.9	35.0	19.0	4.16	7.4	11.0	6.0	1.18
Pn. septomradiatus	20.0	21.0	18.0	1.73	8.7	12.0	4.0	4.16
Ps. argentilineatus	26.4	30.0	21.0	2.72	9.5	11.0	7.0	1.07
Ps. chrysospilos	26.8	32.0	21.0	3.18	7.3	11.0	6.0	1.55
Ps. gracilis	24.7	30.0	18.0	3.67	10.4	13.0	8.0	1.51
Ps. cf. *novaeguineaensis*	29.7	35.0	25.0	3.12	9.1	10.0	8.0	0.73
Ps. novemradiatus	25.6	30.0	20.0	2.33	9.0	13.0	6.0	1.08
Ps. species A	26.7	29.0	25.0	1.49	8.4	10.0	7.0	0.90
S. histophorus					5.0	5.0	5.0	0.00

Table 10. Ranges, means and standard deviations of counts of second dorsal fin rays and anal fin rays.

Species	Second dorsal fin rays				Anal fin rays			
	Mean	Max	Min	sd	Mean	Max	Min	sd
B. boddarti	24.2	27.0	21.0	1.45	24.1	27.0	19.0	1.54
Pn. schlosseri	11.1	13.0	11.0	0.65	11.0	13.0	11.0	0.77
Pn. septomradiatus	12.7	14.0	11.0	1.53	11.3	12.0	11.0	0.58
Ps. argentilineatus	12.4	13.0	10.0	1.00	11.7	13.0	11.0	0.77
Ps. chrysospilos	12.3	14.0	10.0	1.03	11.4	13.0	10.0	0.95
Ps. gracilis	11.8	13.0	11.0	0.83	10.6	12.0	10.0	0.88
Ps. cf. *novaeguineaensis*	12.8	14.0	11.0	0.70	13.4	14.0	12.0	0.62
Ps. novemradiatus	12.3	14.0	10.0	0.91	11.7	13.0	9.0	0.87
Ps. species A	11.4	13.0	9.0	1.18	10.4	12.0	9.0	0.90
S. histophorus	27.3	28.0	26.0	0.94	25.3	26.0	25.0	0.47

Table 11. Ranges, means and standard deviations of measurements and counts of *Boleophthalmus boddarti.*

(All measurements are expressed as a percentage of standard length)

n=172	Mean	Max	Min	sd
Body depth	15.4	18.1	13.0	1.06
Head length	26.5	29.4	14.2	2.28
Head depth	16.0	18.9	11.5	1.01
Head width	16.3	18.7	13.5	1.08
Height of pectoral fin base	9.8	12.7	4.3	1.42
Length of D1 base	8.9	15.2	4.3	1.80
Length of D2 base	39.2	42.5	33.4	1.42
Length of anal fin base	36.8	40.4	34.0	1.26
Caudal fin length	17.7	24.5	8.6	4.04
Pectoral fin length	17.6	22.2	11.0	2.62
Pelvic fin length	14.0	22.5	6.6	2.10
Body depth at least depth of caudal peduncle	8.3	16.3	6.6	1.19
Pectoral fin rays (left)	18.4	21.0	17.0	0.91
Pectoral fin rays (right)	18.6	21.0	17.0	0.93
Longitudinal scales	79.2	106.0	67.0	8.28
Transverse scales	19.9	33.0	15.0	3.27
Predorsal scales	32.0	44.0	25.0	4.06
Spinous dorsal fin	5.0	5.0	5.0	0.00
Total D2 fin elements	24.2	27.0	21.0	1.45
Total anal fin elements	24.1	27.0	19.0	1.54

Table 12. Ranges, means and standard deviations of measurements and counts of *Periophthalmodon schlosseri*.

(All measurements are expressed as a percentage of standard length)

n=21	Mean	Max	Min	sd
Body depth	15.1	16.1	14.2	0.56
Head length	28.0	29.7	26.3	0.95
Head depth	18.1	19.7	16.2	0.86
Head width	18.4	22.4	15.0	1.95
Height of pectoral fin base	12.8	14.5	10.7	1.06
Length of D1 base	13.3	17.2	7.4	2.68
Length of D2 base	21.4	28.3	18.5	2.19
Length of anal fin base	20.5	23.2	18.0	1.11
Caudal fin length	14.9	18.6	12.8	1.30
Pectoral fin length	24.1	26.6	20.7	1.45
Pelvic fin length	14.6	16.4	13.2	0.77
Body depth at least depth of caudal peduncle	9.6	10.4	8.7	0.51
Pectoral fin rays (left)	14.8	18.0	12.0	1.28
Pectoral fin rays (right)	14.0	17.0	12.0	1.11
Longitudinal scales	51.7	62.0	53.0	2.22
Transverse scales	14.0	20.0	12.0	1.93
Predorsal scales	21.9	35.0	19.0	4.16
Spinous dorsal fin	7.4	11.0	6.0	1.18
Total D2 fin elements	11.1	13.0	11.0	0.65
Total anal fin elements	11.0	13.0	11.0	0.77

Table 13. Ranges, means and standard deviations of measurements and counts of *Periophthalmodon septemradiatus*.

(All measurements are expressed as a percentage of standard length)

n=3	Mean	Max	Min	sd
Body depth	15.1	15.4	14.4	0.57
Head length	25.8	26.2	25.5	0.36
Head depth	18.9	19.7	17.7	1.11
Head width	18.1	18.9	16.6	1.32
Height of pectoral fin base	11.9	13.2	10.5	1.34
Length of D1 base	10.2	17.5	0.0	9.12
Length of D2 base	21.1	23.5	18.8	2.30
Length of anal fin base	14.8	15.9	13.9	1.02
Caudal fin length	14.5	15.4	13.1	1.24
Pectoral fin length	22.4	23.0	22.0	0.51
Pelvic fin length	13.3	13.9	12.5	0.70
Body depth at least depth of caudal peduncle	8.1	8.8	7.3	0.76
Pectoral fin rays (left)	13.7	14.0	13.0	0.58
Pectoral fin rays (right)	13.0	13.0	13.0	0.00
Longitudinal scales	57.7	59.0	56.0	1.53
Transverse scales	17.3	23.0	14.0	4.93
Predorsal scales	20.0	21.0	18.0	1.73
Spinous dorsal fin	8.7	12.0	4.0	4.16
Total D2 fin elements	12.7	14.0	11.0	1.53
Total anal fin elements	11.3	12.0	11.0	0.58

Table 14. Ranges, means and standard deviations of measurements and counts of *Periophthalmus argentilineatus*.

(All measurements are expressed as a percentage of standard length)

n=17	Mean	Max	Min	sd
Body depth	13.4	17.5	11.8	1.20
Head length	25.2	30.3	23.6	1.53
Head depth	16.9	18.4	14.4	0.88
Head width	16.5	17.7	14.7	0.96
Height of pectoral fin base	10.5	18.7	9.3	2.16
Length of D1 base	16.9	19.6	13.6	1.61
Length of D2 base	21.1	23.6	19.1	1.16
Length of anal fin base	18.9	20.2	17.2	0.82
Caudal fin length	18.6	20.2	17.1	0.87
Pectoral fin length	22.7	25.2	20.1	1.35
Pelvic fin length	12.3	23.0	10.2	3.28
Body depth at least depth of caudal peduncle	7.3	7.8	6.6	0.34
Pectoral fin rays (left)	11.0	12.0	10.0	0.71
Pectoral fin rays (right)	10.9	12.0	10.0	0.70
Longitudinal scales	66.1	76.0	57.0	5.42
Transverse scales	15.4	18.0	13.0	1.32
Predorsal scales	26.4	30.0	21.0	2.72
Spinous dorsal fin	9.5	11.0	7.0	1.07
Total D2 fin elements	12.4	13.0	10.0	1.00
Total anal fin elements	11.7	13.0	11.0	0.77

Table 15. Ranges, means and standard deviations of measurements and counts of *Periophthalmus chrysospilos*.

(All measurements are expressed as a percentage of standard length)

n=48	Mean	Max	Min	sd
Body depth	14.5	20.0	12.0	1.59
Head length	24.7	26.7	22.7	0.94
Head depth	14.5	16.3	12.4	0.93
Head width	15.5	18.4	14.1	1.10
Height of pectoral fin base	10.3	11.5	8.9	0.84
Length of D1 base	10.5	16.7	5.4	3.15
Length of D2 base	20.4	23.9	17.5	1.48
Length of anal fin base	18.2	20.9	14.7	1.48
Caudal fin length	20.9	24.3	10.7	3.42
Pectoral fin length	23.2	27.3	18.6	2.00
Pelvic fin length	13.1	15.5	10.3	1.10
Body depth at least depth of caudal peduncle	7.9	8.5	7.3	0.34
Pectoral fin rays (left)	13.9	15.0	13.0	0.76
Pectoral fin rays (right)	14.1	15.0	12.0	0.95
Longitudinal scales	72.8	82.0	64.0	5.99
Transverse scales	18.5	21.0	17.0	1.19
Predorsal scales	26.8	32.0	21.0	3.18
Spinous dorsal fin	7.3	11.0	6.0	1.55
Total D2 fin elements	12.3	14.0	10.0	1.03
Total anal fin elements	11.4	13.0	10.0	0.95

Table 16. **Ranges, means and standard deviations of measurements and counts of *Periophthalmus gracilis*.**

(All measurements are expressed as a percentage of standard length)

n=10	Mean	Max	Min	sd
Body depth	12.0	12.8	10.7	0.97
Head length	23.1	23.7	22.6	0.50
Head depth	13.7	14.3	13.1	0.54
Head width	16.2	17.5	15.0	1.06
Height of pectoral fin base	8.9	9.3	8.4	0.43
Length of D1 base	19.3	20.4	17.7	1.18
Length of D2 base	19.3	20.4	17.7	1.18
Length of anal fin base	17.9	19.1	16.2	1.28
Caudal fin length	19.6	20.2	18.9	0.56
Pectoral fin length	21.4	22.7	20.2	1.10
Pelvic fin length	11.0	11.8	10.4	0.63
Body depth at least depth of caudal peduncle	7.0	7.5	6.6	0.40
Pectoral fin rays (left)	11.3	13.0	10.0	1.00
Pectoral fin rays (right)	11.2	12.0	10.0	0.97
Longitudinal scales	61.1	70.0	52.0	6.97
Transverse scales	15.3	19.0	13.0	1.80
Predorsal scales	24.7	30.0	18.0	3.67
Spinous dorsal fin	10.4	13.0	8.0	1.51
Total D2 fin elements	11.8	13.0	11.0	0.83
Total anal fin elements	10.6	12.0	10.0	0.88

Table 17. Ranges, means and standard deviations of measurements and counts of *Periophthalmus* cf. *novaeguineaensis*.

(All measurements are expressed as a percentage of standard length)

n=26	Mean	Max	Min	sd
Body depth	13.3	15.1	12.1	0.74
Head length	24.1	25.7	23.1	0.64
Head depth	16.1	16.7	15.5	0.34
Head width	15.9	17.3	10.0	1.87
Height of pectoral fin base	10.2	11.3	9.0	0.69
Length of D1 base	17.7	21.9	9.8	2.89
Length of D2 base	21.8	23.1	19.5	0.82
Length of anal fin base	21.0	22.6	18.8	1.09
Caudal fin length	18.6	21.3	17.0	1.03
Pectoral fin length	22.7	25.6	20.3	1.48
Pelvic fin length	9.9	11.1	8.9	0.61
Body depth at least depth of caudal peduncle	7.4	8.0	6.7	0.39
Pectoral fin rays (left)	12.3	16.0	10.0	1.49
Pectoral fin rays (right)	12.3	15.0	11.0	1.14
Longitudinal scales	78.5	88.0	69.0	5.56
Transverse scales	17.8	20.0	16.0	1.25
Predorsal scales	29.7	35.0	25.0	3.12
Spinous dorsal fin	9.1	10.0	8.0	0.73
Total D2 fin elements	12.8	14.0	11.0	0.70
Total anal fin elements	13.4	14.0	12.0	0.62

Table 18. **Ranges, means and standard deviations of measurements and counts of *Periophthalmus novemradiatus*.**

(All measurements are expressed as a percentage of standard length)

n=92	Mean	Max	Min	sd
Body depth	14.1	19.1	11.8	1.06
Head length	24.3	26.4	17.3	1.34
Head depth	16.7	19.1	11.8	2.61
Head width	17.3	22.7	13.8	1.22
Height of pectoral fin base	10.8	25.3	8.9	2.29
Length of D1 base	17.1	23.1	11.0	2.78
Length of D2 base	21.6	25.6	18.4	1.42
Length of anal fin base	18.6	25.9	15.9	1.73
Caudal fin length	18.6	25.6	7.0	2.48
Pectoral fin length	22.7	25.9	7.6	2.18
Pelvic fin length	11.8	17.7	10.6	1.00
Body depth at least depth of caudal peduncle	7.8	19.2	6.9	2.38
Pectoral fin rays (left)	10.9	13.0	9.0	0.89
Pectoral fin rays (right)	10.9	13.0	9.0	1.14
Longitudinal scales	64.3	75.0	55.0	4.29
Transverse scales	15.7	19.0	13.0	1.52
Predorsal scales	25.6	30.0	20.0	2.33
Spinous dorsal fin	9.0	13.0	6.0	1.08
Total D2 fin elements	12.3	14.0	10.0	0.91
Total anal fin elements	11.7	13.0	9.0	0.87

Table 19. Ranges, means and standard deviations of measurements and counts of *Periophthalmus* species A.

(All measurements are expressed as a percentage of standard length)

n=17	Mean	Max	Min	sd
Body depth	14.1	15.0	12.7	0.72
Head length	26.8	28.5	25.3	1.00
Head depth	19.5	21.1	17.8	0.93
Head width	20.9	23.0	18.5	1.24
Height of pectoral fin base	11.5	12.9	10.4	0.64
Length of D1 base	14.9	17.5	10.1	2.21
Length of D2 base	17.7	21.9	14.5	2.17
Length of anal fin base	14.9	15.8	14.1	0.44
Caudal fin length	14.2	16.5	12.5	1.20
Pectoral fin length	22.7	26.6	13.4	3.74
Pelvic fin length	13.0	14.2	11.6	0.65
Body depth at least depth of caudal peduncle	8.2	8.8	7.4	0.49
Pectoral fin rays (left)	13.7	15.0	12.0	1.03
Pectoral fin rays (right)	14.0	15.0	13.0	0.53
Longitudinal scales	64.0	71.0	61.0	3.38
Transverse scales	13.9	15.0	12.0	0.99
Predorsal scales	26.7	29.0	25.0	1.49
Spinous dorsal fin	8.4	10.0	7.0	0.90
Total D2 fin elements	11.4	13.0	9.0	1.18
Total anal fin elements	10.4	12.0	9.0	0.90

Table 20. Ranges, means and standard deviations of measurements and counts of *Scartelaos histophorus*.

(All measurements are expressed as a percentage of standard length.)

n=14	Mean	Max	Min	sd
Body depth	8.0	10.2	6.7	1.01
Head length	17.8	21.5	14.8	1.96
Head depth	8.6	10.2	7.6	0.76
Head width	9.6	12.2	8.2	1.22
Height of pectoral fin base	4.9	6.2	4.3	0.52
Length of D1 base	3.9	5.5	2.8	0.77
Length of D2 base	41.3	49.9	37.9	3.44
Length of anal fin base	37.7	45.6	34.0	3.23
Caudal fin length	19.2	23.1	17.6	1.89
Pectoral fin length	10.7	13.4	9.0	1.32
Pelvic fin length	9.7	11.2	8.2	0.98
Body depth at least depth of caudal peduncle	4.6	5.7	3.9	0.53
Pectoral fin rays (left)	18.0	19.0	17.0	0.82
Pectoral fin rays (right)	18.3	19.0	18.0	0.47
Longitudinal scales				
Transverse scales				
Predorsal scales				
Spinous dorsal fin	5.0	5.0	5.0	0.00
Total D2 fin elements	27.3	28.0	26.0	0.94
Total anal fin elements	25.3	26.0	25.0	0.47

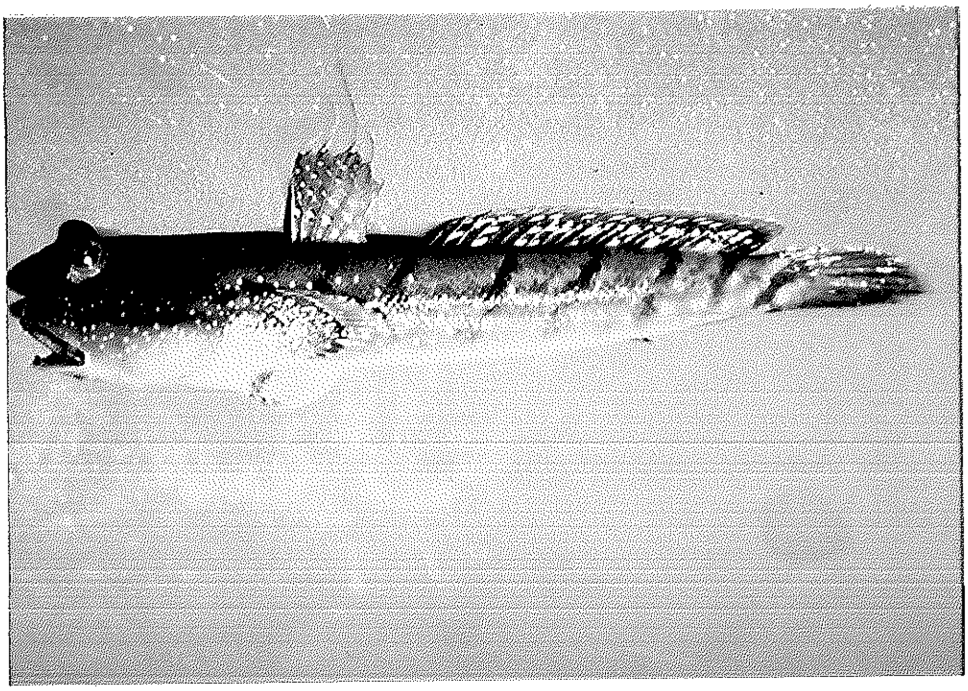

Fig. 16 *Boleophthalmus boddarti* (Pallas)

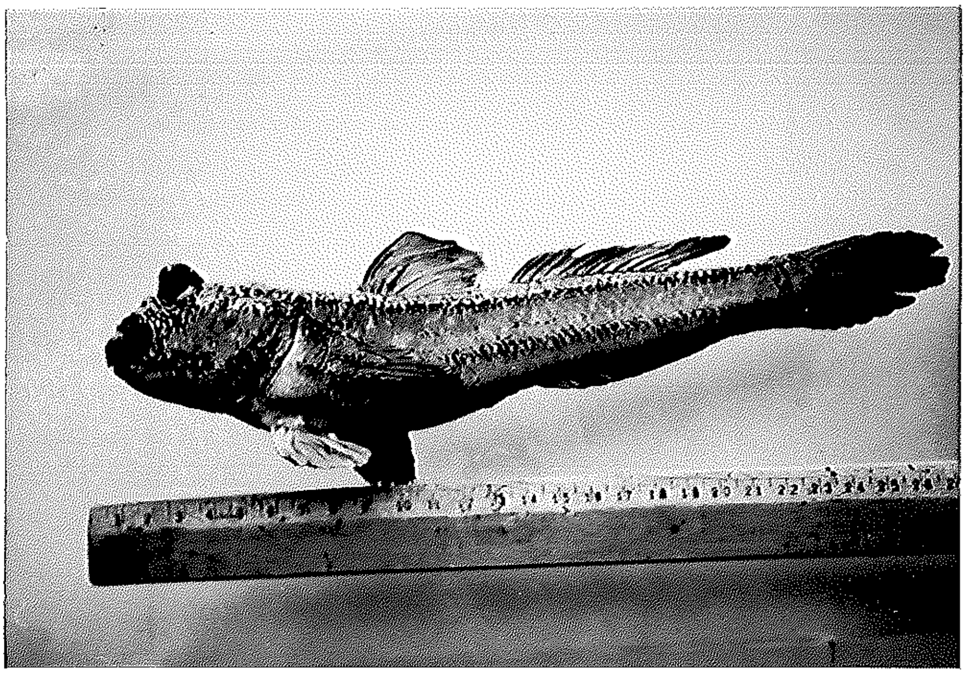

Fig. 17 *Periophthalmodon schlosseri* (Pallas)

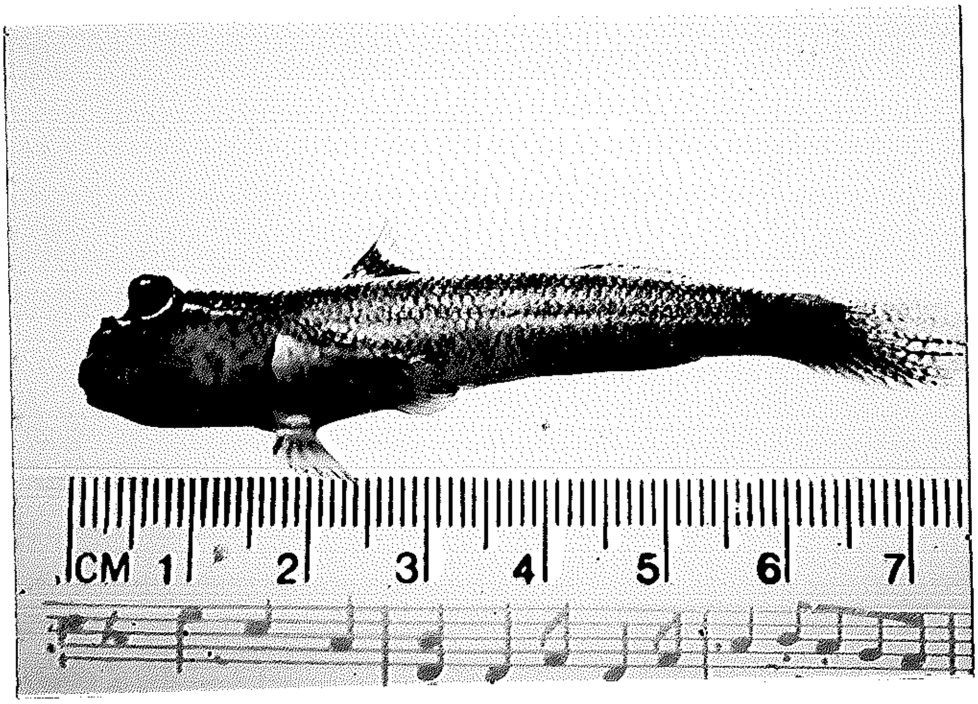

Fig. 18 *Periophthalmodon septemradiatus* (Hamilton)

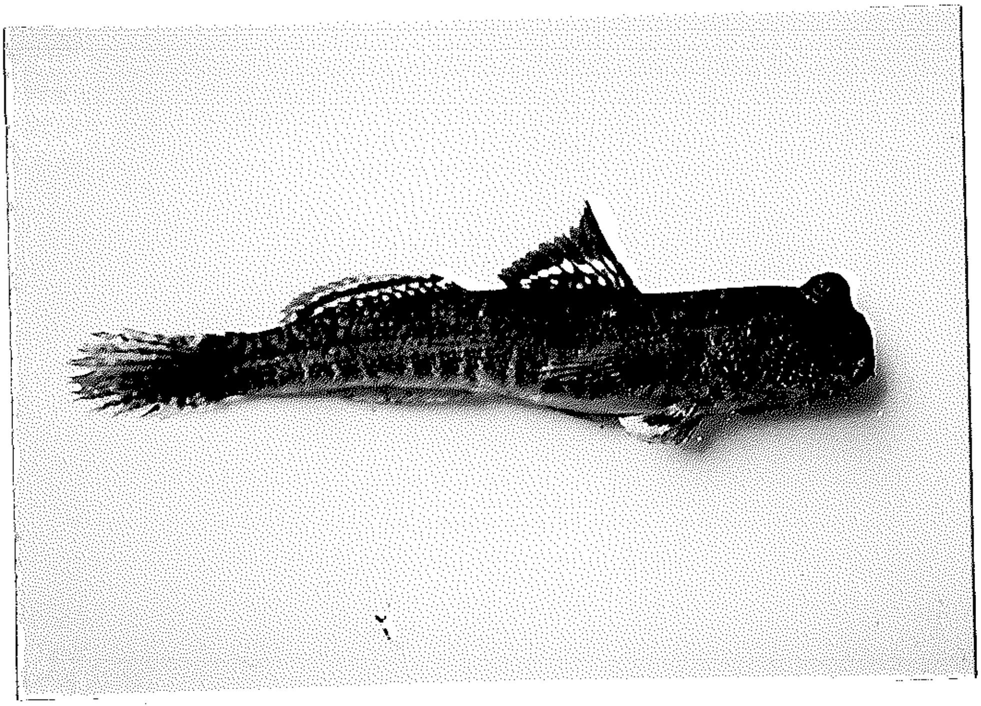

Fig. 19 *Periophthalmus argentilineatus* Valenciennes

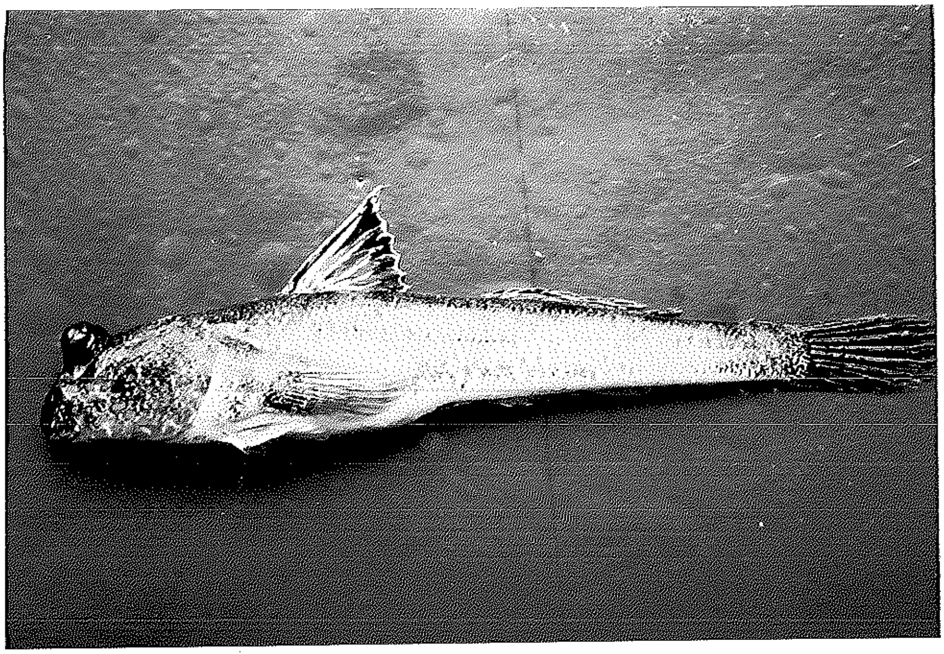

Fig. 20 *Periophthalmus chrysospilos* Bleeker

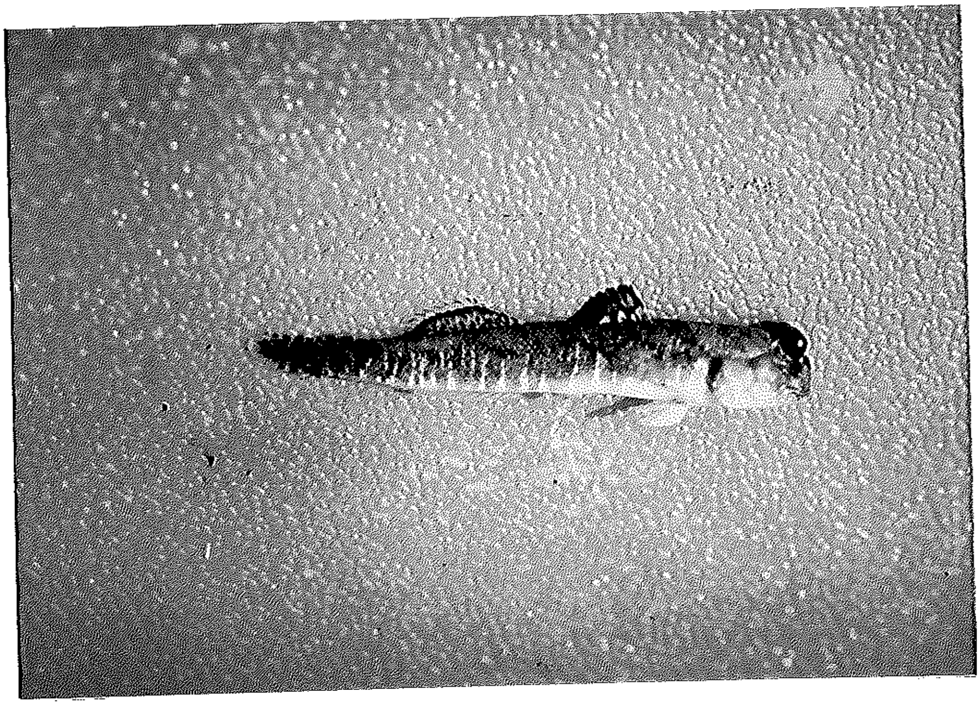

Fig. 21 *Periophthalmus gracilis* Eggert

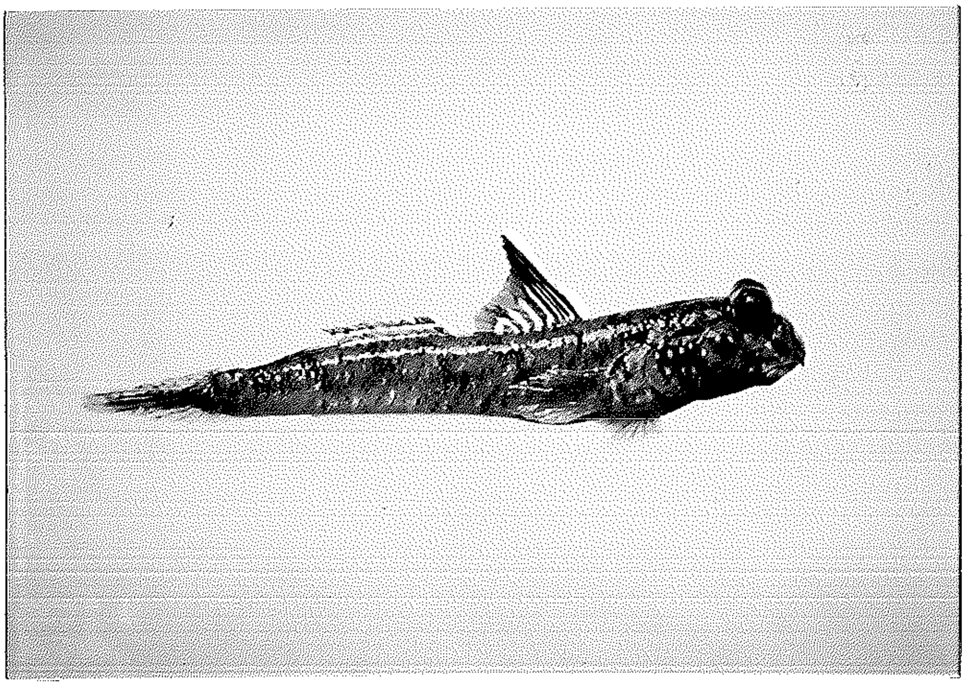

Fig. 22 *Periophthalmus* cf. *novaeguineaensis* Eggert

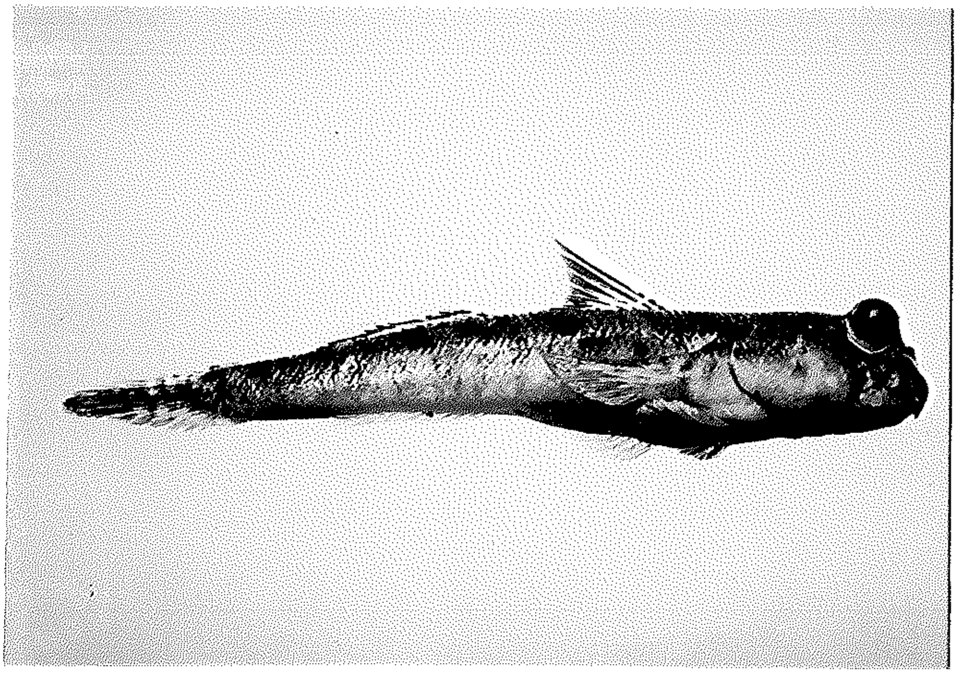

Fig. 23 *Periophthalmus novemradiatus* (Hamilton)

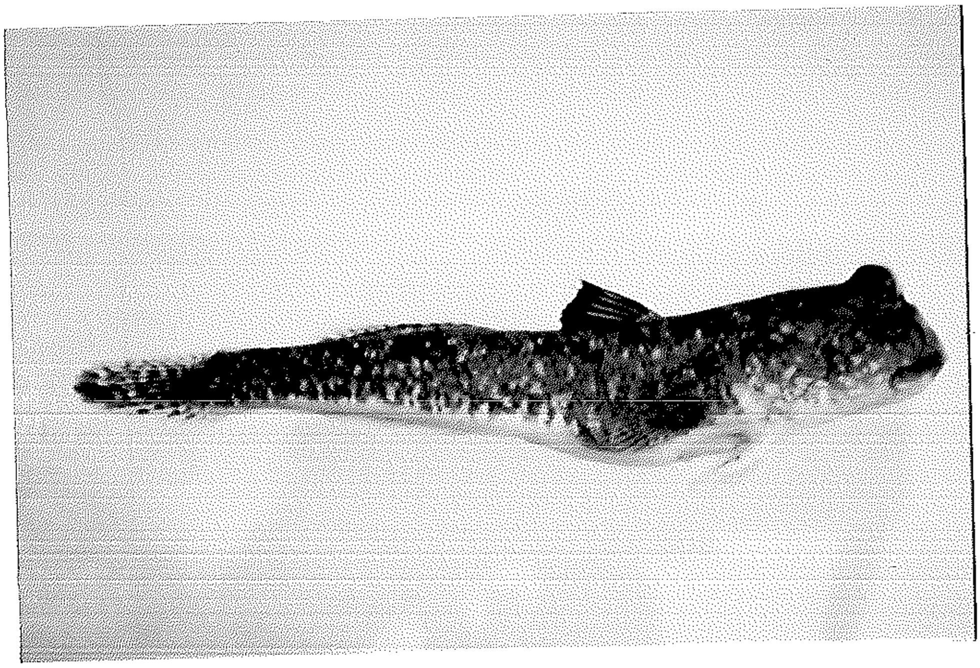

Fig. 24 *Periophthalmus* species A

Fig. 25 *Scartelaos histophorus* (Valenciennes)

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