SOME FEATURES OF THE LIFE HISTORY OF THE COCKSCOMB PRICKLEBACK, ANOPLARCHUS PURPURESCENS GILL

by

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ABSTRACT

The cockscomb prickleback, Anoplarchus purpurescens Gill, family Stichaeidae, ranges from Attu Island and Pribilof Islands, Alaska, to central California. In British Columbia coastal waters it is a bottom-dwelling intertidal species, geographically sympatric with A. insignis, which appears to prefer deeper water than A. purpurescens. A. purpurescens was collected and studied at an intertidal site at Second Narrows, Burrard Inlet, Vancouver, British Columbia.

Morphological variation within the population studied, was examined by both measurements and meristic counts. Data obtained were used to differentiate the population of A. purpurescens used in the study, from its sibling species A. insignis.

Food and feeding habits were studied over a wide range in size, with emphasis on habitat and seasonal differences shown. Relative importances of various food items reflected differences in availability of organisms utilized as food at various tide levels. Food intake is curtailed in adult fish approaching and during the breeding season.

Marking experiments were designed to examine movements, territoriality and homing behaviour. They showed

movements of Anoplarchus to be rather restricted. Fifty-eight percent of recaptured marked fish showed a homing tendency. Marked fish were seldom found more than 50 feet from where originally captured. Territoriality was of the home-range type during non-breeding times of the year. With the beginning of pair formation in advance of spawning, defended territoriality is shown.

Behaviour associated with courtship, parental care and interaction between the sexes subsequent to spawning, is described. Eggs were successfully hatched and the young are described.

Spawning takes place in the months of January and February. The female Anoplarchus guards and tends its eggs. The newly hatched larvae show marked positive phototaxis for three to five days, suggesting a planktonic existence during this period; they then become negatively phototactic and seek the bottom.

Age and growth were examined by the length-frequency method and otolith analysis. The population was found to be composed of individuals from less than one year of age, to greater than five years of age; representing year classes 1959 to 1963. Females show a slightly faster rate of growth than males and are larger than males at every year of age. The sex ratio favours females over almost the

entire range in length exhibited.

The value of exponent n, in length-weight relationship, $W = c L^n$, was found to be 2.98585; log c, -5.31565. The sexes show a similar trend in values of coefficient of condition. The coefficient was at its lowest for specimens collected during the first month of the spawning season. Condition was examined on a size, sex and seasonal basis.

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INTRODUCTION

Anoplarchus purpurescens, commonly known as the cockscomb blenny or prickleback, is a common intertidal fish of the Pacific Northwest, belonging to the family Stichaeidae (suborder Blennioidei). The present study deals with various aspects of the life history of A. purpurescens. The data were obtained during June, 1963, to the spring of 1965, from a site at Second Narrows, Burrard Inlet, Vancouver, British Columbia.

The pricklebacks usually inhabit the cold waters, occurring from the intertidal area to depths of at least 200 fathoms and are bottom dwellers. Clemens and Wilby (1961) report 13 species of pricklebacks occurring in the waters off the Pacific Coast of Canada.

The suborder Blennioidei is believed to be diphyletic, the so-called "eel blennies" (e.g., pholids, stichaeids) are readily separated from the "tropical blennies" (e.g., blenniids, clinids). Details of the life histories of the blennioid fishes, especially the "eel blennies", are not well known. Most studies have considered aspects of reproduction, mainly on representatives of the families Blenniidae and Clinidae. Authors such as Guitel (1893), Pieron (1914), Lebour (1927), Breder (1939,

1951) and Qasim (1955), have presented much of the information known for a number of these latter families.

Studies of the "eel blennies" have been confined mainly to North Atlantic forms. The pholid, Pholis gunnellus, has been studied by Ehrenbaum (1904), Gudger (1927) and Qasim (1955), but only aspects of reproduction were examined. Details of the life histories of the Pacific forms are almost unknown. Metz (1912) reported the finding of a Xerepes fucorum guarding its eggs. Schultz and DeLacy (1932) presented a study of the eggs and nesting habits of Anoplarchus purpurescens.

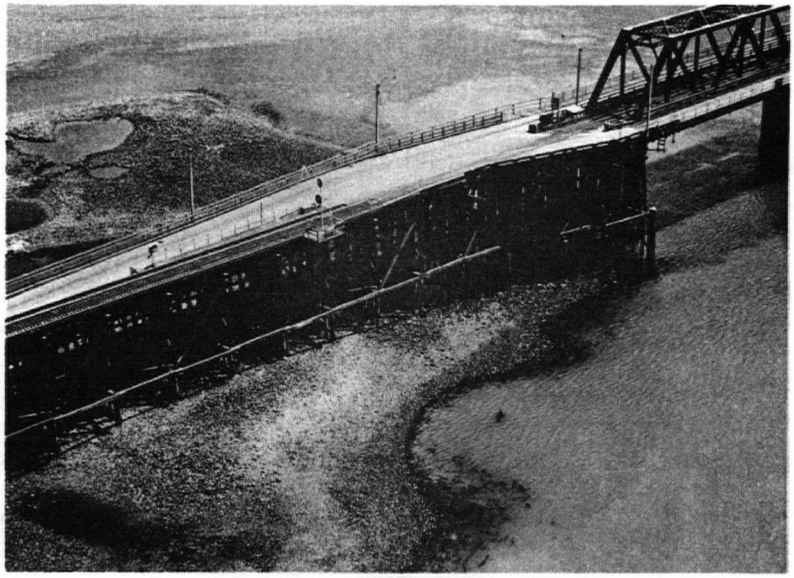
Systematically, A. purpurescens has been well studied, firstly by Hubbs (1927) and secondly, a reexamination of the species by Peden (in press). The reproductive study made by Schultz and DeLacy (1932), however, still represents all that is known on the biology of the species.

THE STUDY AREA

The study area was located at Second Narrows, Burrard Inlet, Vancouver, British Columbia; a latitude of 49°18' North and longitude of 123°01' West. The actual site was situated on the north side of the Inlet, beneath and directly adjacent to the old Second Narrows Bridge (Figure 1). The exposed rows of bridge pilings were used as reference points in collections made and in the marking experiments, and reference will be made to bridge pillar numbers.

Burrard Inlet is a large tidal body of water, extending some 18 miles (29 Kilometres) eastward from the Strait of Georgia. Six miles (9.6 Km.) east of the inlet of English Bay, the Inlet narrows to Lions Gate or First Narrows, a deep channel about one mile (1.6 Km.) and 1,200 feet (365.7 metres) wide. This channel opens into the main portion of Burrard Inlet, containing Vancouver Harbour. Vancouver Harbour is about five miles (8.0 Km.) long and one and one-half miles (0.8 Km.) wide. Five miles (8.0 Km.) east of First Narrows, Burrard Inlet again contracts to form Second Narrows, which is about one mile (1.6 Km.) long and 2,500 feet (762 m.) wide. From Second Narrows, the Inlet extends eastward some seven miles (11.3 Km.)

A.



B.

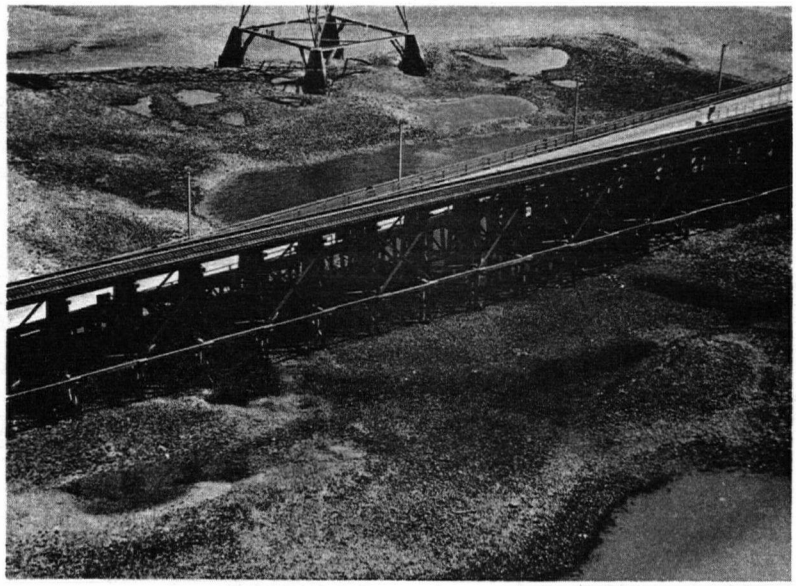


Figure 1. The study area; photographed from the west side of the old Second Narrows bridge, Burrard Inlet. A. Section referred to by pillar numbers 1 to 6. B. Section referred to by pillar numbers 7 to 14.

The north shore of the Inlet is deeply scored by rivers, the largest of which are the Capilano, Lynn and Seymour. The Seymour River opens into Burrard Inlet just a few hundred feet from the study area.

The shoreline of the north shore consists of tidal flats, and for the most part, has a very muddy substrate.

Tidal variation at Vancouver (latitude 49°17'N; longitude, 123°07'W) is as follows (Canadian Hydrographic Service, 1964):

	higher high water	lower low water
mean tides	12.4	2.1
large tides	14.2	-1.7
recorded extremes	16.0	-2.6

Tidal current at Second Narrows is strong, varying in velocity from 0.5 to 5.5 knots (Canadian Hydrographic Service, 1964).

Habitat

I searched extensively for the species in the Second Narrows area. Animals were only common in the area beneath and directly adjacent to the old Second Narrows Bridge. Here, unlike areas close by, the muddy substrate

is well masked by sand, rocks and gravel, except for regions in the upper-intertidal and lower low-intertidal zones.

Along the length of the bridge (north-south direction) are aggregations of rocks, highly irregular in size and shape. In the mid-intertidal zone and upper low-intertidal zone, these rocks tend to be aggregated, and do not press firmly into the substrate, thus providing many spaces for habitation by fishes and invertebrates. In contrast, rocks of the upper-intertidal and lower low-intertidal zones tend to be dispersed and also press firmly into the muddy substrate.

It is under the rocks of the mid-intertidal and upper low-intertidal zones where Anoplarchus abounds. The habitat extends approximately 260 feet along the length of the bridge. Collections and studies in the field were carried out in a total area of approximately 14,300 square feet. The latter figure includes the area beneath the bridge and the area east and west, directly adjacent to the bridge. The full extent of habitat was only exposed on the very low low tides of less than one foot, but low tides of up to two feet were used for mid-intertidal work.

Inhabitation of the intertidal area demands a close association with the substrate of rocks and stones,

for shelter during periods of intertidal exposure. With its slender and compressed body, Anoplarchus is able to slide beneath and between rocks where other fish and invertebrate species would not find access. The shelters not only function as places of refuge during periods of intertidal exposure, but are important sources of bottom-dwelling invertebrates utilized as food (for example, polychaete worms and flatworms). During the breeding season, the shelters become the nesting sites. The eggs are laid beneath the rocks in small depressions, either natural or made by the spawning pair, or in vacant clam shells.

Distribution of Anoplarchus over the area studied appears closely correlated with the character of the substrate (rocks not embedded, substrate beneath damp but not muddy), but also with the distribution of algae. Not only does green algae form a major part of the diet, but it is the habitat of many invertebrates utilized as food (for example, amphipods, isopods, mussels and littorine snails).

Animal Associates

In the intertidal zones inhabited by Anoplarchus, many of the spaces beneath the rocks are used by other fish and invertebrate species. The shore crabs,

Hemigrapsus nudus and H. oregonensis, are abundant in the mid-intertidal zone and occupy the majority of the available spaces beneath the stones in the uppermost region of this zone. Anoplarchus and Hemigrapsus, although sometimes being very close together, seldom share the same stone. This latter situation was observed by Schultz and DeLacy (1932), who stated that the crabs appeared to occupy the spaces under the more loosely associated stones, while Anoplarchus occurred under the more closely fitting stones. This is an observation which appears to hold true for this area as well. In this zone, the hermit crab, Pagurus, is common in the tidepools and occasionally beneath stones.

In the lower portion of the mid-intertidal and low-intertidal zones, the larger crabs, Cancer magister and C. productus are located in tidepools and beneath rocks. In the low-intertidal zone, the kelp crab, Pugettia, is commonly seen beneath stones in the area.

Mid-intertidal and deeper, the pholids, Pholis laeta and P. ornata are found, beneath rocks and in the tidepools. Numbers seen were never great, but observation has shown that Pholis does utilize the habitat along with Anoplarchus for breeding purposes in January and February. Observed egg masses of Pholis, along with the guarding

parents, were located lower down on the beach than those of Anoplarchus, amongst the kelp beds.

Tidepool sculpins, Oligocottus maculosus, are common in the tidepools of the mid-intertidal zone and occasionally stranded beneath stones in the area. Other larger cottids are seldom seen, although the occasional Artedius is found stranded mid-intertidally or lower. In the low-intertidal zone, the clingfish, Gobiesox meandricus is often seen attached to the under-surfaces of stones.

Predators

Clemens and Wilby (1961) in their account of Pacific Coast fishes, mention that many of the larger species feed on small fishes such as sculpins and blennies, but the specific names of those fish consumed are not given. Members of the following families most likely play a role in the predation of Anoplarchus, at least during some season of the year, or, some time in its life cycle: Gadidae, Pleuronectidae, Hexagrammidae, Scorpaenidae, Cottidae and possibly Salmonidae. Stomach content analysis was not performed on any representatives of these families, but from the knowledge of their presence in the area (collections made by the Institute of Fisheries, U.B.C., and the accounts of Clemens and Wilby, 1961) they possibly play some role.

A known predator, at least in the Friday Harbour area of San Juan Island, Washington, is the common garter snake, Thamnophis sirtalis (Batts, 1961). An examination of the gut contents of 10 snakes by this author showed that five had been feeding on intertidal fishes. Four stomachs possessed Anoplarchus; two snakes with one fish per stomach and the other two snakes with three fish per stomach. Other fish in the stomachs of these snakes were the clingfish, Gobiesox meandricus and the rock prickleback, Xiphister atropurpureus (=Epigeichthys atropurpureus).

SYSTEMATICS

Capture and Preservation of Specimens

All specimens used in this part of the work were part of the regular collections made from the study area. Eighty-four specimens taken from June, 1963, to May, 1964, were used for the variation study.

Upon collection in the field, the fish were placed into a 10% solution of formalin and were later transferred to 40% isopropyl alcohol. Each collection was washed free of formalin with running tap water for several hours before transfer to alcohol. The latter procedure was always completed within 24 hours after collection. Thus, no samples were left in formalin for more than 24 hours, and a standardized procedure was followed for all samples.

Methods Employed in the Measurements and Counts

Measurements

Most methods employed in the measurements followed Hubbs and Lagler (1958); some however, do not follow their guide and are noted as follows:

Standard Length--distance from anterior point of head (tip of upper jaw in this species) to posterior point of caudal peduncle (point marking bases of caudal rays).

Total Length--the latter measurement, plus length of caudal fin.

Head Depth--from posterior end of cockscomb to a point just behind posterior end of jaws.

Depth of Body at Anus--perpendicular distance from outside edge of dorsal fin to anal opening (measurement therefore includes height of dorsal fin at this point).

Cockscomb of Head--three dimensions: length, distance along base of structure from anterior point to posterior point; greatest width, width of structure (outer edge to outer edge) at a point just behind posterior margin of orbit; greatest height, perpendicular distance of structure near posterior end of cockscomb (just posterior to point of width measurement).

In all measurements the sexes were treated separately. As wide a range as possible in standard length of the body was selected of each sex. In the cockscomb analysis, the fish were separated as to immature and mature, as well as to sex.

Counts

Counts were made of the dorsal, anal, pectoral and caudal fin rays and spines. Methods of Hubbs and Lagler (1958) were employed.

In the anal fin, the last two rays were counted as two rays.

Counts were made from preserved (a few cleared and stained) specimens. The standard procedure for clearing and staining was employed.

The length of the scaly area of the body was also examined, using cleared and stained specimens for this observation.

Classification

Anoplarchus purpurescens Gill, is a perciforme teleost belonging to the suborder Blennioidei, family Stichaeidae (Regan, 1912; Hubbs, 1927; Berg, 1941; Makushok, 1958). Makushok (1958) places the families Stichaeidae, Pholidae, Anarrhichadidae and Ptilichthyidae within the super-family Stichaeoidae. Within the family Stichaeidae he places eight subfamilies with their thirty genera. The genus Anoplarchus is placed within the sub-

family Alectriinae along with the genera Alectrias and Pseudalectrias. Thus, within the subfamily Alectriinae, according to Makushok, there are three genera and five species, Anoplarchus and Pseudalectrias being monotypic and Alectrias having three species.

Alectrias is considered by Makushok to be the most primitive genus in the subfamily, with Anoplarchus very close, being distinct from Alectrias in having the gill membranes widely separated by the isthmus. Pseudalectrias has retained the broadly joined gill membranes which are free from the isthmus, but has diverged from Alectrias in the following features: loss of scale covering, absence of palatine teeth and reduction in both pyloric caecae and dermal crest.

Hubbs (1927), considering Anoplarchus to be monotypic, subdivided the genus into three subspecies, Anoplarchus purpurescens insignis Gilbert and Burke, A.p. purpurescens Gill and A.p. archolepis Hubbs. Characters used for this subspecific separation were number of dorsal spines, number of anal rays and extent of the scaly area of the body.

Recent data presented by Peden (in press), demonstrates that Anoplarchus insignis Gilbert and Burke and Anoplarchus purpurescens Gill, previously considered

subspecies, are valid sibling species. A. insignis differs from A. purpurescens by possessing higher meristic counts and having a narrower width between the points of attachment of each gill membrane to the isthmus. The subspecies which have differentiated within these two species were not evaluated.

A. insignis ranges from Attu Island, Alaska, to Puget Sound and the Strait of Juan de Fuca. It shows an increased number of dorsal spines and anal fin rays over A. purpurescens. Latitudinal variation in the number of spines according to Peden, is 57-64; in the number of anal rays, 40-46. Scales on the posterior part of the body extend anteriorly to between seventh and fifteenth anal fin ray.

A. purpurescens has a wide range, from Attu Island and the Pribilof Islands, Alaska, to central California. Latitudinal variation in number of dorsal spines according to Peden, is 54-59; in number of anal rays, is 36-42. Scales on the posterior half of the body extend anteriorly to between the twelfth anal fin ray and origin of anal fin or anus.

Synonymy: Anoplarchus purpurescens.

The following list of synonymy follows Hubbs (1927), with further additions which have occurred in the

literature since Hubbs' paper.

Ophidium, "Species dritte", Kittlitz, Denkwurdigkeiten einer Reise nach dem russischen Amerika, etc,1, 1858, p 225, fig. 3.

Anoplarchus purpurescens Gill, Proc. Acad. Nat. Sci. Phila., 1861, p 262.

Centronotus crista galli Günther, Cat. Fishes Brit. Mus., 3, 1861, p 289.

Anoplarchus crista galli Günther, ibid, p 564; Jordan, Evermann and Clarke, Rept. U.S. Comm. Fish., for 1928, Pt. 2, p 468.

Anoplarchus alectrolophus Jordan and Gilbert, Proc. U.S. Nat. Mus., 3, 1880, p 265; 3, 1880 (1881), p 454 (in part); Jordan and Jouy, ibid, 4, 1881, p 4; Jordan and Gilbert, ibid, p 64 (in part).

Anoplarchus atropurpureus Jordan and Gilbert, Proc. U.S. Nat. Mus., 3, 1880, p 265; Bean, ibid, 4, 1881, p 245; 4, 1881 (1882), p 468; Jordan and Gilbert, Bull. U.S. Nat. Mus., 16, 1883, p 771; Bean, Proc. U.S. Nat. Mus., 6, 1883 (1884), p 354; Jordan, Rept. U.S. Comm. Fish., 1885, p 910; Turner, Contr. Nat. Hist. Alaska, 1886, p 93; Eigenmann and Eigenmann, Ann. N.Y. Acad., 6, 1892, p 357; Jordan and Starks, Proc. Cal. Acad. Sci., (2):5, 1895, p 846; Gill, Proc. U.S. Nat. Mus., 18, 1895

(1896), p 150; Starks, Proc. Calif. Acad. Sci., (2):6, 1896, p 562; Gilbert, Rept. U.S. Comm. Fish., 1893 (1896), p 450; Jordan and Evermann, Bull. U.S. Nat. Mus., 47, Pt. 3, 1898, p 2422; Pt. 4, 1900, fig. 845; Rutter, Bull. U.S. Fish. Comm., 1898 (1899), p 192; Jordan and Gilbert, Fur Seals and Fur-Seal Islands, 3, 1899, p 483; Osgood, N. Am. Fauna, 21, 1901, p 20; Evermann and Goldsborough, Bull. U.S. Bur. Fish., 26, 1906 (1907), p 338; Starks, Ann. Carn. Mus., 7, 1911, p 212; Gilbert and Burke, Bull. U.S. Bur. Fish., 30, 1910 (1912), p 88; Halkett, Check fishes Canada, 1913, p 111; Miles, Publ. Puget Sd. Biol. Sta. 2, 1918, pp 79, 93; Kincaid, Annotated list Puget Sd. Fishes, 1919, pp 41, 42, fig. 96; Bean and Weed, Trans. Roy. Soc. Canada, (3), 13, 1919 (1920), pp 81, 82.

Anoplarchus Fraser, Can. Field Nat., 35, 1921, p 48.

Description of Anoplarchus purpurescens

Body moderately elongate, slender, compressed. Caudal peduncle short, deep and compressed.

Skin with small embedded scales, confined to posterior half of body and extending anteriorly as far as

between twelfth anal fin ray and origin of anal fin or anus; portion of body anterior to this naked. Lateral line weakly visible; short. Sensory (seismosensory) canals of head normally developed, opening out with a constant number of pores; nasal 2, interorbital 4, postorbital 7, occipital 4, suborbital 6, preopercular 6 and mandibular 4 (Makushok, 1958).

Head small, moderately pointed in profile; lacking spines, cirri or barbels; with a rostral-occipital fleshy crest. Mouth terminal, moderately large, oblique. Lower jaw included; lips on both upper and lower jaws fleshy. Teeth on jaws, vomer and palatines. Snout pointed in profile, lacking spines or other armature. Nostrils paired, lying just ahead of orbits, one on either side of dermal crest. Eye relatively small, ovate. Preopercle and opercle unarmed; posterior edge of opercle fleshy. Branchiostegal rays 5. Gill membranes broadly united, broadly coalesced with isthmus.

Fins: dorsal fin composed of spines only, those in anterior portion weak and flexible and acquiring more stoutness and rigidity towards rear of fin; commences above or slightly in advance of pectorals and ends at base of caudal; anal fin composed entirely of soft rays, commences immediately behind anus and ends at base of caudal; caudal fin with wide base and convex outer border; pectoral fins

moderately large, outer borders convex; pelvics lacking.

Anoplarchus purpurescens in the area where collected for this study and in adjacent waters, can be distinguished from all other blennioids by: absence of pelvic fins, presence of the dermal crest on the head, scales on the posterior part of the body only and the great width between the points of attachment of each gill membrane to the isthmus.

The species was first recorded in British Columbian waters in 1861 from Vancouver Island and the mouth of the Fraser River by A. Günther as Centronotus crista galli (Clemens and Wilby, 1961). Specimens were collected during the voyage of H.M.S. Plumper. The species was called the crested blenny in 1946 by Clemens and Wilby, the American Fisheries Society / American Society of Ichthyologists and Herpetologists recommends simply "cockscomb" (Clemens and Wilby, 1961).

Results of Measurements and Counts

Measurements

Results of measurements of body parts are shown in Tables I and II. Forty-two males, ranging in standard

length from 51.5 to 123.5 mm, and 42 females ranging in standard length from 66.2 to 128.0 mm, were measured.

Table I. Ranges and means of body measurements, shown in actual measurements; 42 males and 42 females.

Measurement	Males		Females	
	Range	Mean	Range	Mean
Head length	8.7- 21.8	15.77	10.7- 20.0	15.50
Head depth	5.6- 15.5	10.62	7.0- 13.8	10.33
Head width	5.0- 12.8	9.02	6.1- 12.0	8.97
Snout length	1.8- 5.7	3.62	2.1- 5.1	3.52
Interorbital width	1.2- 2.8	2.00	1.4- 2.5	1.91
Orbit length	1.8- 3.8	2.91	1.9- 3.8	2.94
Depth body at anus	6.9- 17.5	13.97	9.1- 19.5	14.26
Length dorsal	43.8-103.0	79.98	56.0-106.8	82.25
Length anal	28.5- 67.1	53.07	38.0- 71.9	54.44
Length caudal	5.1- 11.3	8.62	5.9- 12.1	8.89
Length pectoral	4.0- 9.9	7.10	4.5- 10.0	7.10

The ranges and means for the sexes are similar, and do not show dimorphism.

Results of cockscomb measurements are shown in Table III. Of immatures, 19 males, ranging in standard length from 51.5 to 108.0 mm, and 19 females, ranging in standard length from 65.0 to 121.0 mm, were used; of matures 13 males, from 83.0 to 123.5 mm, and 13 females, from 89.0 to 128.0 mm, were used. Differences between means were tested statistically.

Table II. Ranges and means of body measurements, shown in frequencies into standard and head lengths; 42 males and 42 females.

Measurement	Males				Females			
	Into S.L.		Into H.L.		Into S.L.		Into H.L.	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Head length	5.44-7.12	6.06			5.77-6.81	6.30		
Head depth			1.33-1.67	1.48			1.33-1.62	1.49
Head width			1.47-1.95	1.74			1.47-2.13	1.74
Snout length			3.44-5.78	4.43			3.73-5.72	4.37
Interorbital width			5.84-9.18	7.88			6.68-9.53	8.09
Orbit length			4.45-6.25	5.39			4.31-6.31	5.28
Depth body at anus	5.93-8.10	6.84			5.77-8.05	6.86		
Length dorsal	1.14-1.28	1.19			1.12-1.30	1.19		
Length anal	1.69-1.90	1.80			1.52-2.02	1.79		
Length caudal			1.61-2.04	1.83			1.47-2.08	1.74
Length pectoral			1.95-2.64	2.23			1.82-2.58	2.19

Table III. Measurements of cockscomb, shown in actual measurements; 19 immature males and 19 immature females; 13 mature males and 13 mature females.

Measurement	Immature		Mature	
	Range	Mean	Range	Mean
Males				
Length	5.9-12.0	9.05	9.8-15.9	12.6
Greatest height	1.2- 2.9	1.96	2.0- 4.9	3.28
Greatest width	1.2- 2.5	1.91	1.9- 3.6	2.77
Females				
Length	6.9-13.1	9.26	9.1-12.9	11.6
Greatest height	1.3- 3.0	2.02	2.0- 3.4	2.75
Greatest width	1.4- 2.8	1.95	1.8- 2.8	2.22

Counts

Results of meristic counts are shown in Table IV; frequencies of counts are shown in Figure 2.

Table IV. Meristic counts; 20 fish, 4 cleared and stained.

Meristic	Range	Mean
Dorsal fin spines	55-58	56.75
Anal fin rays	38-41	39.35
Caudal fin rays-principal	11-13	12.45
-total	15-16	15.75
Pectoral fin rays	9-10	9.05
Length of scaly area		
- farthest forward	3-4 anal ray	
- commonest	4-5 anal ray	

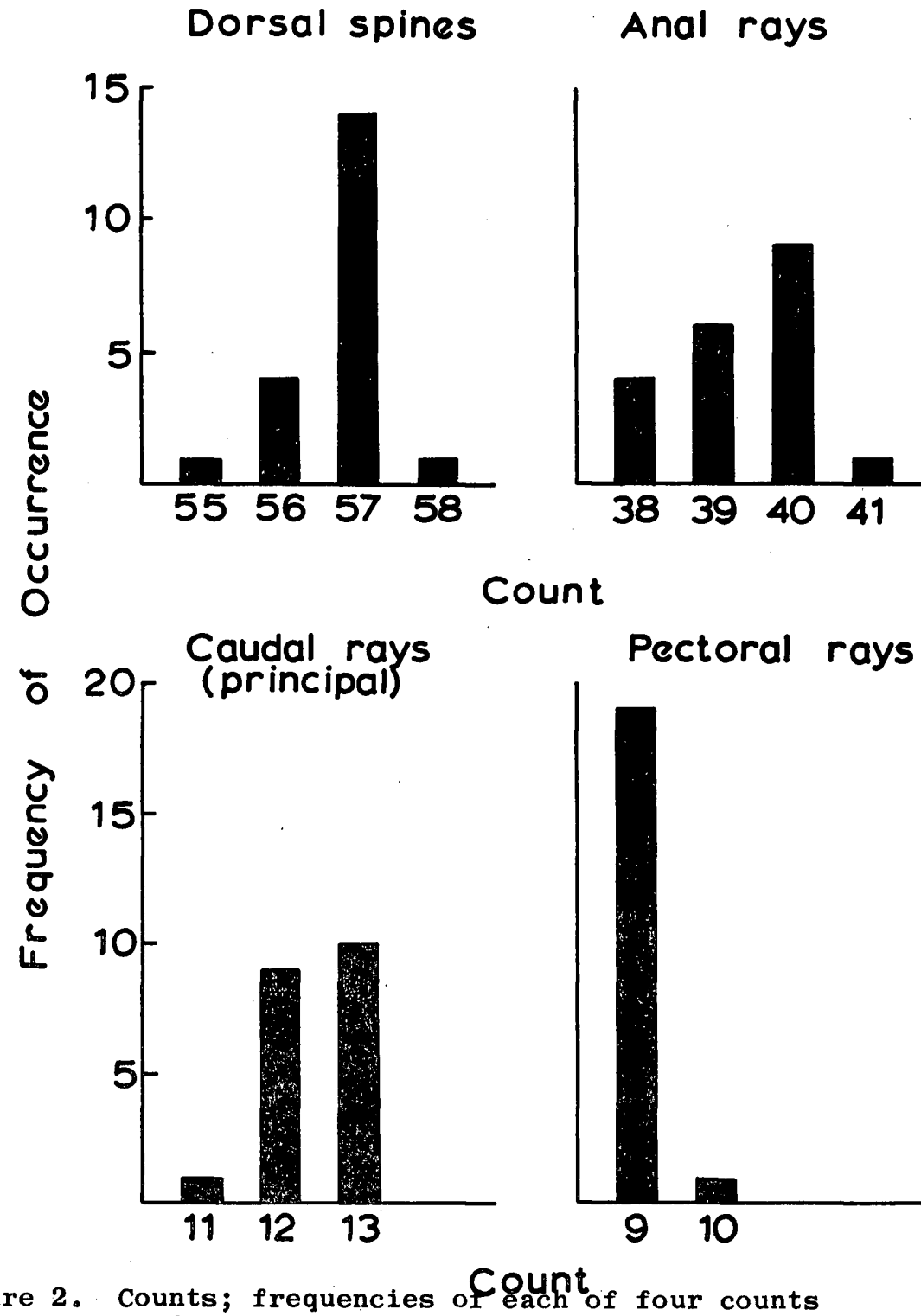


Figure 2. Counts; frequencies of each of four counts performed.

Results of T-Tests on Cockscomb Data

All tests were carried out on actual measurements.

(1) Mature males were found to be significantly different, at the 1% level, in all three dimensions of the cockscomb from immature males.

(2) Mature females were found to be significantly different, at the 1% level in length and height, and the 5% level in width, from immature females.

(3) Mature males were not significantly different (5% level) from mature females in length of cockscomb, but were significantly different in height (5% level), and in width (1% level).

(4) Immature males were not significantly different (5% level) in any dimension of cockscomb from immature females.

Discussion

Available data from collections of Anoplarchus examined by Peden (in press), indicates that A. insignis prefers deeper water than A. purpurescens. Peden also

points out that in British Columbia A. insignis is distributed almost entirely in the subtidal zone.

On the basis of information gathered from meristic counts and measurements made in this study, it appears that the intertidal population of Anoplarchus used was entirely A. purpurescens.

FOOD AND FEEDING

Introduction

The feeding habits or feeding behaviour of fishes are the search for and ingesting of food. These should be distinguished from food habits and diet, which are materials habitually or fortuitously eaten.

Food studies based on contents of digestive tracts or of faeces, merely show what an animal will eat. Because of natural fluctuations in abundance, any one food organism is not always of constant numerical availability. Such fluctuations of forage organisms are often cyclic and due to factors of their life histories or to climatic or other environmental conditions.

Fishes may be classified according to the amount of variation in types of food consumed by them:
(1) euryphagic --feeding on a variety of foods;
(2) stenophagic--feeding on a few different types of foods;
(3) monophagic --feeding on only a single type of food.

The fish eats those types of food to which it is adapted. The food of fishes may be divided into several categories according to the relationship between fishes and their food. Nikolsky (1963) divided the food of fishes

into three categories, realizing that the classification was to some extent subjective:

(1) basic food--that which the fish usually consumes, comprising the main part of the gut contents;

(2) secondary food--frequently found, but in smaller amounts;

(3) incidental food--only rarely enters the gut.

A study of feeding habits may be of great help in reducing limitations imposed on food habits by differential rates of digestion of various food organisms. Thus, determination of when an animal feeds would facilitate the collecting of specimens close to or during that time, so that foods in the stomach would be relatively whole, undigested materials, whether the organisms eaten are soft- or hard-bodied.

Availability of food organisms was assessed qualitatively by observation and collection of algae and invertebrates. A quantitative estimate was not attempted. The term "availability" is used here as defined by Hess and Swartz (1940), implying those organisms which are capable of being eaten by the fish if it so desires. Thus, it is distinct from food "preference", which as Hess and Swartz point out, should only be used to refer to a definite exercising of choice by the fish.

Method

Of the five most commonly used methods of analysis of food habits the method of frequency of occurrence was selected and used in all food analyses presented in this study. This method of analysis characterizes the distribution of a given food species, and together with the variety of foods, shows the feeding uniformity of a population. It does not, however, indicate the quantitative value of a given food species.

In order to determine frequency of occurrence, the number of individual stomachs in which was found each kind of food item was recorded. Results are expressed as a percentage of the total number of specimens containing food.

Specimens were left intact until examination of stomachs was to be performed. Standard length, sex and condition of gonads were recorded for each specimen. Gonads were left attached to the body cavity for future examination. The stomach was cut free from the esophagus and intestine, and slit open. The contents were spread on a white-bottomed dissecting tray and sorted using a dissecting microscope. Examined contents were then stored in glass vials.

The stomach was the only portion of the gut used for recording frequency of occurrence of food material. In cases where either the stomach was devoid of food and/or the intestine was swollen with material, the intestine was examined. Food material present was not recorded as an occurrence of food. Information gathered from such examination showed to what extent food organisms were broken down and therefore helped to identify material that was partially digested in the stomach.

Results

Composition of Food

The results are given in Table VI. (See Table VII for more specific identification of food organisms.)

Correlation of Habitat and Types of Food Eaten

Examination of data reveals a close similarity in those organisms eaten to those organisms present in zones of the beach where fish were collected. Table VIII and Figure 3 show the frequency of occurrence of each food item for each sample of fish examined. The areas of collection of these samples and general characteristics of these areas

Table V. Areas of collection of samples for food analysis, with comments on reference points used and general characteristics of areas.

Date of Sample	Reference Points, Characteristics and General Remarks
Aug., 1963 Sep., 1963 Dec., 1963 Mar., 1963	All collected between pillars 8-14, beneath or very closely adjacent to the understructure of the bridge. Uppermost region of the mid-intertidal sampled; characterized by dense growths of mussels and heavily-barnacled rocks. Tangled masses of nemertean worms among mussels and on pilings. A few tidepools present at the bases of outer-most bridge pilings. Green algae present.
May, 1964	Collected between pillars 8-12, west side of bridge. Low-intertidal; characterized by green algae-covered rocks and kelp beds.
Jun., 1964 Jul., 1964 Aug., 1964 Sep., 1964 Oct., 1964	All collected between pillars 1-6, beneath and east and west sides of bridge. Mid-intertidal and low-intertidal; characterized by mussel beds and heavily barnacled rocks in the mid-intertidal region and kelp beds in the low-intertidal region. Presence of polychaete worms very apparent. Kelp beds of green, brown and red algae. Tidepools present, usually drain on lowest tides.

Table VI. Percentage frequency of occurrence of all items found to be food organisms. Total percentage breakdown of 242 stomachs sampled.

Food Organism	No. of Occurrences	Percentage
Algae	77	32.35
Roundworms	42	17.65
Amphipods	37	15.55
Flatworms	30	12.60
Nemertean Worms	13	5.46
Mussels	8	3.36
Shrimp	7	2.94
Isopods	7	2.94
Nereid Worms	5	2.10
Littorine Snails	2	0.84
Other	10	4.20
Stomachs with food present	195	80.58
- stomachs with identifiable food	159	81.54
- stomachs only with digested matter	36	18.46
Stomachs completely devoid of food	47	19.42

are shown in Table V.

Two more striking similarities which arise from the data are: (1) high frequency of occurrence of numertean worms in those samples collected in the upper mid-intertidal zone; and (2) the increase in frequency of occurrence of polychaete worms (referred to as roundworms in the tables and figures) and amphipods in those samples collected in the mid-intertidal and lower zones. Observation and collection of organisms in these zones has shown the availability

of these food items.

Table VII. Classification of organisms found in the food analysis. After, Borradaile and Potts (1961); Johnston and Snook (1927); Ricketts and Calvin (1962); Scagel (1957).

A. Algae

CHLOROPHYCOPHYTA
Order Ulotrichales
Family Ulvaceae- *Ulva*

RHODOPHYCOPHYTA

B. Invertebrates

PLATYHELMINTHES
Class Turbellaria
Order Polycladida- *Notoplana*

NEMERTEA
Class Enopla
Order Hoplonemertini
Emplectonema gracile
Paranemertes

ANNELIDA
Class Polychaeta
Family Nereidae- *Nereis*
Family Terebellidae- *Thelepus*

ARTHROPODA
Class Crustacea
Subclass Malacostraca
Order Peracarida
Suborder Isopoda
Cymothoidea- *Cirolana*
Suborder Amphipoda
Gammaridea
Family Gammaridae
Family Talitridae
Family Amphithoidae
Order Eucarida
Suborder Decapoda
Macrura
Family Cragonidae- *Crago*

Table VII (cont'd.)

B. Invertebrates

MOLLUSCA
Class Gastropoda
Order Prosobranchiata
Suborder Pectinibranchiata
Family Littorinidae- *Littorina*
Class Lamellibranchiata
Order Filibranchiata
Family Mytilidae- *Mytilus edulis*

Table VIII. Total percentage breakdown for each of 10 samples examined. Percentage frequency of occurrence of each food item found in the stomachs.

% Stomachs	Aug. 1963	Sep. 1963	Dec. 1963	Mar. 1964	May 1964	Jun. 1964	Jul. 1964	Aug. 1964	Sep. 1964	Oct. 1964
With food	76.2	82.4	75.0	42.9	94.4	94.7	85.7	82.5	90.9	59.1
-iden. food	57.2	50.0	25.0	35.8	94.4	81.5	78.6	80.0	54.6	59.1
-only dig. matt.	19.0	32.4	50.0	7.1	0	13.2	7.1	2.5	36.3	0
Empty	23.8	17.6	25.0	57.1	5.6	5.3	14.3	17.5	9.1	40.9
Number sampled	21	34	16	14	18	38	28	40	11	22
Algae	20.0	20.0	0	40.0	37.1	48.8	35.6	26.5	50.0	22.7
Roundworms	6.6	0	20.0	0	31.4	11.6	27.0	14.3	25.0	22.7
Amphipods	6.6	15.0	0	0	20.0	20.9	13.5	22.4	12.5	0
Flatworms	26.6	15.0	20.0	0	0	0	0	22.4	0	50.0
Nemerteans	13.3	30.0	60.0	40.0	0	0	0	0	0	0
Shrimp	0	0	0	0	0	9.3	8.1	0	0	0
Mussels	0	10.0	0	0	0	0	8.1	6.1	0	0
Isopods	6.6	5.0	0	0	2.9	2.3	2.6	4.1	0	0
Nereids	6.6	0	0	0	2.9	2.3	0	0	0	0
Littorines	0	5.0	0	20.0	0	0	0	0	0	0
Other	13.3	0	0	0	5.7	4.7	2.6	4.1	12.5	0

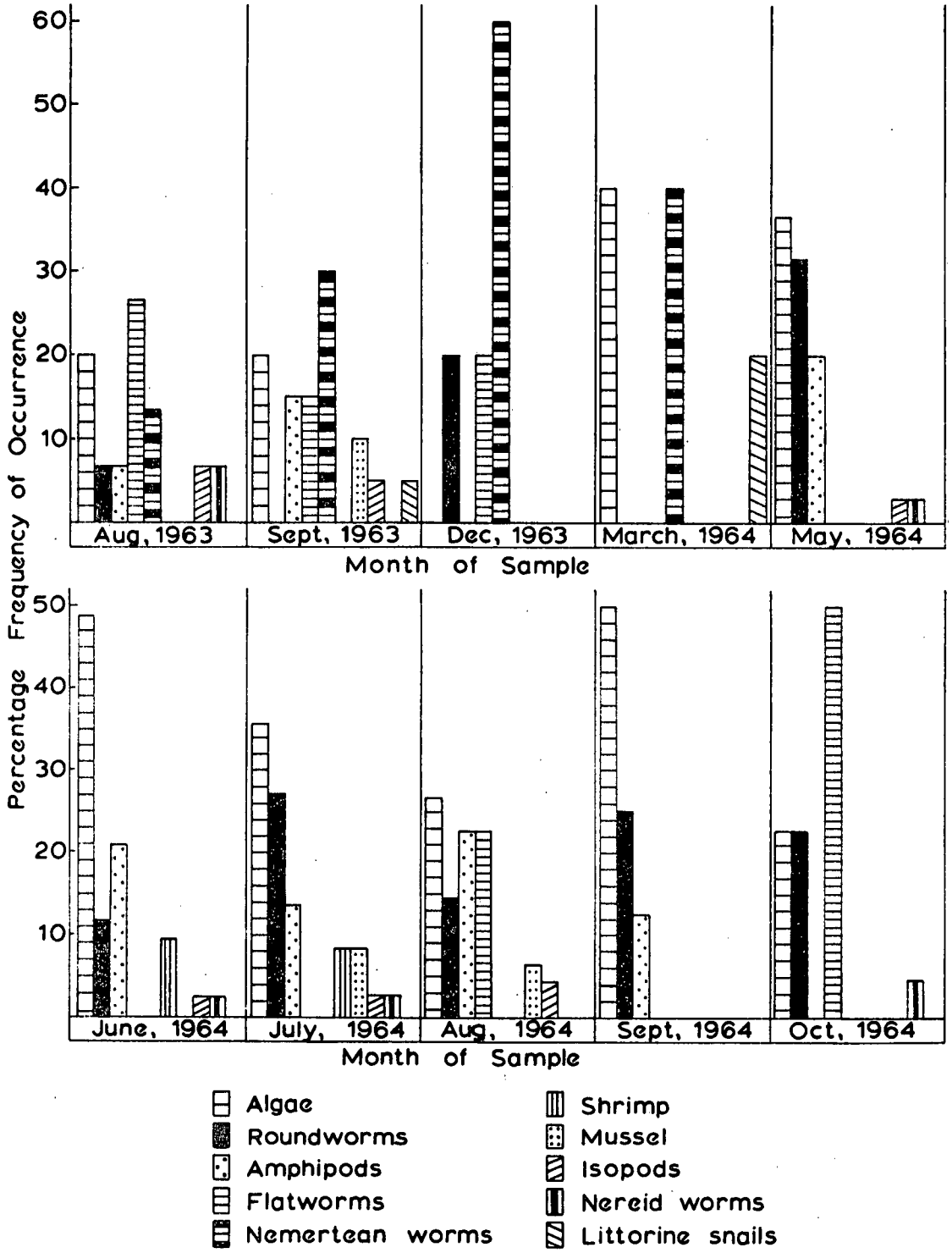


Figure 3. Percentage frequency of occurrence of food items for each of 10 samples examined, arranged in a seasonal sequence.

Littorine snails are confined to the high- and mid-intertidal zones. These snails were found only in samples collected in the upper mid-intertidal zone. Small shrimp were commonly seen under rocks and algae in the low-intertidal zone and showed up only in stomachs of those fish that were collected in the mid-intertidal zone and lower.

The frequency of occurrence of algae in stomach contents was the greatest of all food items, and was almost entirely confined to green algae. Traces of red algae were found in some individuals that were collected at the low-intertidal level, but occurrences were rare. Brown algae were never found in stomachs examined.

Green algae are available from upper to lower levels of the intertidal, whereas browns and reds are confined to lower levels and the sub-tidal. The frequency of occurrence of algae rose with the samples collected from the mid-intertidal and lower but the type of algae remained the same.

Size of Fish vs Size of Foods Eaten

Table IX and Figure 4 show frequency of occurrence of various foods eaten by different lengths of fish

Table IX. Percentage frequency of occurrence of foods eaten by different lengths of fish examined. Lengths arranged in standard length groupings of 5 mm each.

Standard Length	Algae	Round-worms	Amphi-pods	Flat-worms	Nemer-teans	Shrimp	Mussels	Isopods	Nereid worms	Littorine snails
50- 55			100.0							
55- 60										
60- 65	20.0	40.0	20.0							
65- 70	35.7	42.9	7.1				7.1		7.1	
70- 75	40.0	20.0	20.0	20.0						
75- 80		33.3		16.7			16.7		33.3	
80- 85	38.5	23.1	15.4	23.1						
85- 90	35.0	20.0	15.0	10.0	10.0	5.0	5.0			
90- 95	45.8	20.8	20.8	4.2		4.2				
95-100	37.5	15.6	25.0	9.4	3.1	3.1	3.1			
100-105	24.4	9.8	14.6	9.8	12.2	4.9	2.4	7.3	2.4	4.9
105-110	29.0	16.1	6.4	22.6	6.4	3.2	6.4	3.2	3.2	
110-115	34.8	17.4	13.0	21.7	4.3			4.3		
115-120	28.6	4.8	14.3	14.3	9.5	4.8	4.8	9.5		
120-125	50.0		50.0							

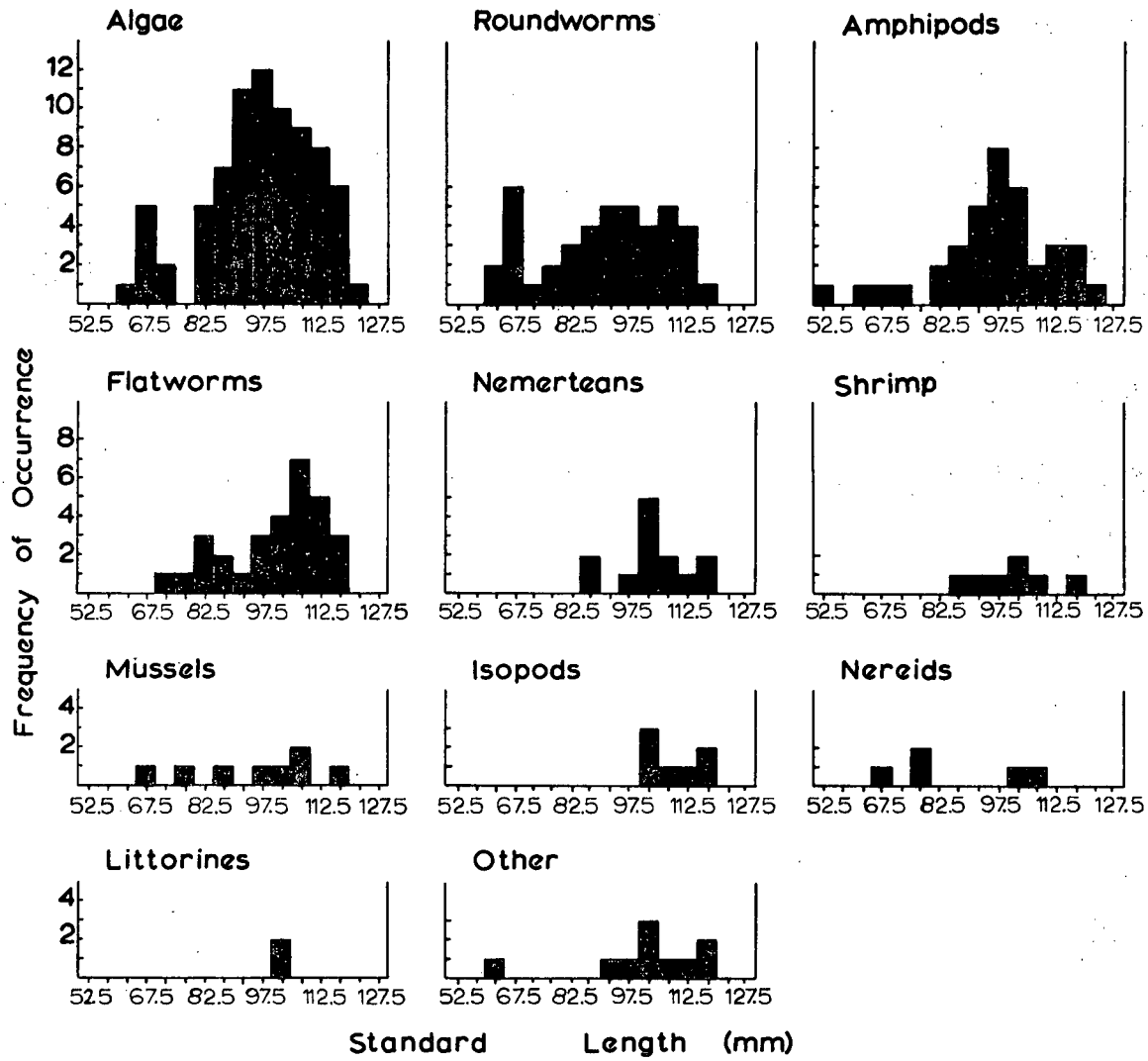


Figure 4. Frequency of occurrence of foods eaten by different lengths of fish examined. Lengths arranged in standard length groupings of 5 mm. each.

examined.

The four most commonly found food organisms in the stomachs, algae, roundworms, amphipods and flatworms respectively, were found to be present over the greatest size range. Nemertean worms, shrimp, and isopods were confined to larger individuals. The mussels eaten were of very small size and occurred somewhat sporadically over a wide range in size. Nereid worms occurred very sporadically over a wide size range, but smaller individuals were only consuming parts of these worms. Littorine snails were confined to a larger size group. Materials classified as "other" included such items as spawn, crustacean appendages and barnacle shells, and were almost entirely confined to larger individuals.

Discussion

Samples of fish were collected during the lowest low-tide of the day. This tide occurs from just before and shortly after midnight, in fall and winter, to before and afternoon, in spring and summer. The tide previous to this low low-tide therefore, either appears during daylight or darkness depending on the season. It is during tides previous to the low low-tide that Anoplarchus must feed.

Figure 5 shows the seasonal changes in percentages of stomachs with and without food. The percentage of empty stomachs and stomachs with only digested matter, rises in fall and winter samples, but remains at a low level during late spring and summer samples. The high incidence of food in stomachs of spring and summer samples indicates that the fish were not only feeding well during these months, but that they were feeding during the high tide before the area was uncovered by water and collections made.

The increase in percentage of empty stomachs in fall and winter could be taken to indicate that fish were not feeding to the same extent as they were in spring and summer. But the increase in stomachs with only digested matter indicates that fish were still feeding but the time of feeding had shifted, so that organisms present in the stomachs were now digested beyond identification. Feeding was therefore taking place during the early part of the previous high-tide or during the low-tide before the high-tide.

The data then suggest that Anoplarchus is a daylight feeder. Thus, there would tend to be a greater percentage of identifiable food items in the stomachs of those fish collected during daylight hours (spring and summer samples), for the fish would have been able to feed during

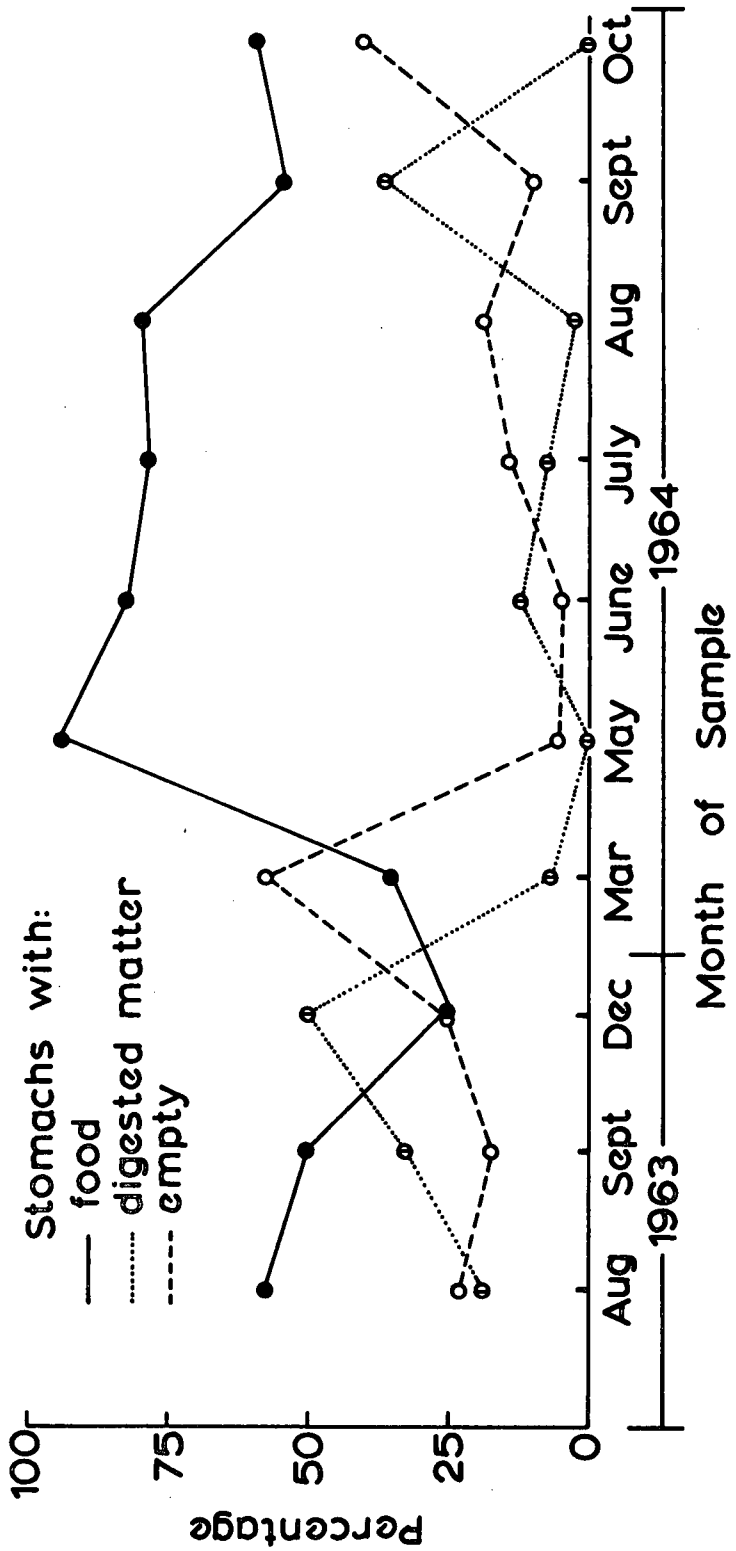


Figure 5. Percentage stomachs with food, only digested matter and empty. Samples arranged in a seasonal sequence.

the previous high-tide. Food in the stomachs of those fish collected in fall and winter would have been present in the gut for a much greater time and therefore would consist of only digested matter by the time of actual collection. Varying rates of digestion and variation in actual feeding times, would account for those food items which appeared relatively undigested, in fall and winter samples.

Anoplarchus appears to be utilizing as food those organisms present and available in the particular habitat at the time of feeding. In samples from August, 1963, to and including, March, 1964, foods found to be present in the stomachs examined can be classified as follows:

(1) basic food -- nemertean worms, algae and flatworms;
(2) secondary food -- roundworms, amphipods and littorine snails;
(3) incidental food -- mussels, isopods and nereid worms.

The remaining 1964 samples show a distinct change in frequency of occurrence of various food items and thus, in their relative importance as foods. In these samples, foods found to be present may be classified as follows:

(1) basic food -- algae, roundworms and amphipods;
(2) secondary food -- flatworms;
(3) incidental food -- all remaining food organisms could be considered in this category.

These changes in relative importance of various food items show differences in availability of organisms utilized as food at different tidal levels of the intertidal zone. It is not implied that changes reflect food preferences, or a definite exercising of choice by the fish.

Alga was a very frequently occurring food item in almost every sample studied. Regardless of differences in habitat, the only alga eaten was green algae (except for rare traces of red algae), even in the low-intertidal where all three types of algae are readily available. Thus, in the utilization of this food item there appears to be a definite exercising of choice by the fish.

On the basis of previous categorization of organisms utilized as food, Anoplarchus can be considered rather stenophagic in its food habits.

Food habits of small and large Anoplarchus are not markedly different. Those foods classified as basic foods were frequently occurring over almost the entire size range studied. Some larger food organisms however, were absent in stomachs of smaller-sized individuals. For the most part, these foods were classified as incidental foods. Nereid worms, largest of organisms utilized as food, occurred rather sporadically over a wide range in fish size. It appears that smaller individuals were utilizing these worms

as food only once they are dead, as small portions only showed up in the stomachs of these fish.

Food intake appears to be curtailed in adult Anoplarchus approaching and during the breeding season (January and February). Percentages of stomachs devoid of food were highest for the samples of December, 1963, March, 1964, and October, 1964; 25.0%, 57.1% and 40.9%, respectively. The May, 1964, sample showed an extremely large increase in food intake, with only 5.6% of stomachs devoid of food.

As will be discussed in detail in a later section, pairing up of sexes begins approximately a month before actual spawning takes place. Pairing becomes noticeable in December, and of course is extremely prevalent during the period January-March when actual breeding is taking place. During the time from pairing to breeding, movements are likely to be at a minimum and therefore the only food consumed would be that which was washed in close to the breeding pair. Schultz and DeLacy (1932) expressed the same opinion when they examined stomachs of guarding females and found them to be devoid of food.

Observation of pairs kept in aquaria for spawning purposes has revealed that the fish will feed if they are provided with food but no deleterious effects are observed if they are not fed. Two such pairs, plus a female and her

eggs, were kept for a period exceeding one month without food of any kind; spawning and hatching occurred.

MOVEMENTS

Introduction

The main objectives of marking experiments were to obtain data on movements, extent of home-range and the possibility of a homing behaviour.

The term "home-range" is adopted here as it was defined by Dice (1952), namely "the area over which an individual animal habitually travels while engaged in his usual daily activities". The home-range includes all feeding sites, breeding sites and places of refuge habitually used by the individual and all other areas regularly traversed by him. This definition has no implication of any tendency on the part of the individual to exclude others of the species from the area. The home-range, or part of a home-range, defended against other members of the same species, is termed a "territory" (Dice, 1952). Many other workers in animal behaviour use the term territory to refer only to this type of defended area (Nice, 1941; Collias, 1951; Carpenter, 1958).

The distinction between defended and home-range territory cannot always be maintained in practice, since our knowledge of the natural behaviour of animals under the

varied natural conditions of their lives is often insufficient to enable us to say to what extent others are excluded from the territory. Natural populations cannot usually be observed to learn whether or not a fish is defending an area, although marking experiments may indicate that movement is restricted.

The features that are defended and even the tendency to defend at all, may vary with the season and with the physiological state of the individual (Dice, 1952; Etkin, 1964). Thus, as Etkin (1964) pointed out, using "territory" as an unqualified term would be useful for such cases, and the term could readily be changed and qualified as home-range or defended as our knowledge justifies.

The idea that some fishes have a home-range has been amply substantiated by several recent workers, notably Newman (1956), Funk (1957), Miller (1957), Williams (1957), Bardach (1958), and Gerking (1959). Most of the work of these authors hinges on the assumption that if a marked fish is caught two or more times in a restricted area, it is likely that the fish has occupied this area for a substantial period of time.

As Gerking (1959) and Williams (1957) pointed out, any quantitative expression about size of the home-range and degree of straying from this area, describes

techniques of the investigator as much as behaviour of the fish. The best that can be hoped is to determine whether or not the movements of a particular species are restricted and to get a general idea about the degree of movement.

Homing behaviour of fishes has been quite extensively studied, the main emphasis having been on freshwater species. The term "homing" has been used in a variety of senses. Usually homing implies the return of mature fish to the place of their own genesis for the purpose of spawning, for example, reproductive homing, as defined by Lindsey, et al. (1959). The typical example of homing of this type is the salmon, but it has also been shown for the shad (Hollis, 1948; Vladykov, 1950).

More general types of homing, not necessarily associated with reproduction, exist in many fish. Gerking (1959) in a summary on non-reproductive homing, defined it as "the choice that a fish makes between returning to a place formerly occupied instead of going to other equally probable places." Williams (1957) implies, in his definition, a periodic return of a certain animal to a certain area that is small compared to the total home-range.

Such homing is known in a variety of intertidal animals. The tidepool fishes show a remarkable homing characteristic. The gill-finned goby, Bathygobius

soporator, has been shown by Beebe (1931) and Aronson (1951) to possess such a behaviour. The fish leave their home-pools at high tide and find their way back at low tide by jumping directionally across the sand separating the pools. Williams (1957) demonstrated that the wooly sculpin, Clinocottus analis and the opaleye, Girella nigricans, come back to the same tidepools on successive low tides. Eastman (1962) showed the same behaviour in the tidepool sculpin, Oligocottus maculosus. It is likely that such a behaviour is also shown by the surf perch, Amphigonopterus aurora Hubbs, 1921).

Among invertebrate intertidal animals, the limpets especially, have been shown to possess such a behaviour; Acmaea (Hewatt, 1940), Lottia (Wells, 1917) and the European Patella (Orton, 1914, 1928; Jones, 1948). Some limpets, however, do not home (Villee and Groody, 1940).

Laboratory Study of Tags

Before marking in the study area commenced and during the first few marking experiments, fish were marked and observed in the laboratory. The first sample was collected on June 25, 1963, a second sample on August 8, 1963, and a third sample on September 13, 1963.

The first sample (14 fish) was distributed equally between two aquaria; a stainless steel tank of five gallons capacity and an iron tank of approximately ten gallons capacity. Both aquaria at the start of the tests were devoid of sand and plants but each had a few rocks.

Tagging of the first sample was not done until the morning of June 27, 1963. At such time nine fish were tagged; four fish in the larger tank and five in the smaller tank, the remaining fish in each tank were left untagged as controls.

Description of the Tag and Method of Tagging

The tag used consisted of two components, a small (2 by 2 mm) embroidery bead and a short piece of nylon fishing leader of 3 or 4 pound test. The bead was attached to one end of the leader leaving a long trailing piece for attaching the tag to the fish.

Tagging of the first sample of fish was performed without the aid of an anesthetic. An anesthetic was used in all the field work, the use of which will be described in a later section. Tagging was accomplished in the following manner. The fish was placed on a small cheesecloth-covered board dampened with sea water. Corners of

the cloth were folded over the body of the fish, leaving only the anterior and mid-portion of the dorsal fin exposed. In this way wriggling movements were held at a minimum and the area to which the tag was to be applied was in view. The tag was then threaded on to a fine needle and the needle passed through the musclature of the back just under the dorsal fin. The bead end of the tag was then pulled closer to the body of the fish and the leader end sewn through the bead and a knot formed. Superfluous leader material was removed after the knot was formed.

The second sample of fish (9 fish) was arranged on August 9, 1963. Five fish were tagged and the rest were left as controls. These fish were placed in the larger aquarium.

The last sample (8 fish) was placed in the smaller tank on September 14, 1963. No individuals of this sample were tagged.

All fish were observed daily for any noticeable effects as a result of the tags or any shedding of tags.

To simulate more natural conditions, on August 21, 1963, the larger tank was set up with sand and rocks. By equipping the tank in this manner the fish were allowed to burrow under the rocks and present the tags with a

condition that they would be more likely to come across in the field. Occasional draining of the tank (with the fish left in the tank) increased their burrowing.

Results

Table X summarizes the results obtained, showing deaths which occurred and shedding of tags.

Table X. Mortalities of marked and unmarked fish observed during laboratory study of tags.

Date of Marking	No. Marked	No. Controls	Dates of Mortalities	No. Marked	No. Unmarked
June 27, 1963	4	3	July 8, 1963	1	
			July 29, 1963	1*	1
			Aug. 5, 1963	1	1
June 27, 1963	5	2	Aug. 26, 1963		1
			Sep. 12, 1963	1	1
			Sep. 13, 1963	4	
Aug. 9, 1963	5	4	Aug. 26, 1963	3	2
			Oct. 17, 1963	2	2
Sep. 14, 1963	-	8	Sep. 18, 1963		5
			Sep. 21, 1963		3

* Tag shed.

Discussion

The swimming of the fish did not appear to be hampered in any way by the tags. All fish, whether tagged or not, fed actively, both on the bottom of the tank and mid-water in the tank, when given such food as frozen brine-shrimp.

Of all the fish tagged only two deaths could be directly attributed to the wearing of tags. These two fish showed the following characteristics before their subsequent death:

(1) area of body directly around base of the tag well "worn" and "raw" in appearance;
(2) adjacent area of body a pale grayish in colour;
(3) general paleness of body colour;
(4) reduction in activity during feeding, to total absence of feeding.

Development of these symptoms was characteristic and once a fish reached "4" death resulted in a matter of a few days.

These symptoms, however, were the extreme conditions and were only shown by two fish, one of which had been wearing the tag for 32 days and the other for 35 days. Another fish however, lived for 60 days without showing

this extreme tag damage to the body. The death of this latter fish was directly attributable to an air supply failure.

Slight "wearing" of the flesh around the tag was shown by the other tagged fish, but conditions did not develop to the extreme shown by the two fish previously described. Deaths, whether the fish were tagged or not, were mainly attributable to air supply failure or some contamination of the water supply. One such air supply failure occurred on August 23, 1963, and was not noticed until August 26, 1963. Five fish (3 tagged, 2 untagged) died as a result of this failure. The last sample of fish died within a week of captivity. Cause of death was unknown.

The tag used was considered useful, even if it could only be worn for one month in the field. Marking experiments planned were to be of short-term and therefore the tag would be reliable.

Laboratory Study of Anesthetics

From the previous lab work on tags and the tagging method it became obvious that this method would not prove satisfactory in the field unless an anesthetic was used. The anesthetic would help speed up the process of tagging

and also help reduce the harmful after-effects of the tagging procedure.

Tricaine Methanesulfonate (MS222) was the first tried and used in the field. The concentration used was entirely arbitrary and because of this, no fish were allowed to remain in the solution longer than the time it took them to become anesthetized. Thus the number of fish which could be properly handled at any one time was small. At the concentrations used, the time to anesthetize was on the average about 2 to 3 minutes. About 4 to 5 minutes were required for recovery.

MS222 was used in all field experiments conducted in 1963, but in 1964, another anesthetic was laboratory tested and used in all subsequent field experiments.

Laboratory Tests on Propylene Phenoxetol

Bagenal (1963), showed that propylene phenoxetol was a useful anesthetic for periods of up to one hour when at a solution of 0.01 to 0.025% and can be used at normal laboratory and aquarium temperatures with fish of a wide range in size. He concluded that for anesthetizing fish for a period of more than three hours, it must be used with great care since the strength of solution and temperature

are critical.

On January 10, 1964, a sample of eight fish was collected and tests were applied on January 11, 1964.

Method

Three concentrations, 0.05%, 0.025% and 0.1% respectively, were set up with one fish per solution. The time to anesthetize (ceasing of all movement when touched, and rolling over on back or side) was noted. Each fish was then placed in fresh sea water and the time to recover (maintenance of an upright posture and movement) noted.

Three concentrations, 0.05%, 0.025% and 0.033% respectively, were set up with two fish in the first two concentrations mentioned and one fish in the remaining concentration. The fish were then left in the solutions for a total of 30 minutes, with the time to anesthetize noted in each case.

Each fish of the sample of eight, was used only once. The Temperature varied about 14.0°C.

Results

Table XI summarizes the data obtained from tests

Table XI. Results of laboratory tests on propylene phenoxetol; A. Anesthetizing and recovery times for three concentrations; B. Anesthetizing and recovery times observed in the 30 minute duration experiment on three concentrations, with comments on breathing movements observed.

	Conc. of Soln. %	Time to Anesthetize (min.)	Time to Recover (min.)	Remarks
A.	0.05	6	9	
	0.025	18	14	
	0.10	4	20	
B.	0.05	5	36	No external signs of breathing (opercular movements ceased); 15 minutes in fresh sea water before first signs of breathing observable.
	0.025	17	13	Slight opercular movements observable; breathing increased almost instantaneously upon placement into fresh sea water.
	0.033	8	21	Opercular movements ceased; breathing increased after about two minutes in fresh sea water.

performed on the anesthetic. Anesthetizing and recovery times are shown with comments on breathing movements observed in the duration experiment.

Discussion

After all tests were completed, the fish were placed in an aquarium and observed over a two-day period for any noticeable harmful effects from the anesthetic. No such effects were observed.

The concentration of 0.033% propylene phenoxetol was chosen to be used in field marking experiments. This concentration gave a fairly short (8 min.) anesthetizing time and the recovery time was not as long as the 0.05% solution (21 min. as opposed to 36 min.), after 30 minutes duration in the appropriate anesthetic solutions. Considering the use to which the anesthetic in the field would be put, the 0.033% concentration appeared to be suitable.

Marking Technique

Preceding each marking experiment, tags were made and set into a perforated sheet of plastic (3" x 3"). Three plastic pails at the time of marking were standard; one for collecting, one for anesthetizing and one for allowing

recovery from anesthetic.

Collection and marking of fish was done during the lowest tide of the day. Locating fish was simply a matter of turning over stones in the appropriate habitat. Fish located in such a manner were captured with gloved hands. A pair of nylon-cotton gloves, dampened with sea water, was used for handling all live fish (except those anesthetized). Unnecessary damage to the fish due to slithering through the hands and falling to the ground, was kept at a minimum by wearing gloves.

Once captured, fish were placed into a plastic pail of fresh sea water. When a number (usually not exceeding more than 15 fish at any one time) had been collected, they were transferred to the anesthetic solution.

The actual marking procedure was as follows: The anesthetized fish was laid out on a dampened cheesecloth-covered plastic sheet (4" x 8"). A needle which had been previously threaded with the tag, was then passed through the musclature of the back, just under the dorsal fin, approximately 1 to 1 1/2 inches from the most anterior point of this fin. At this point, the body of the fish is held somewhat more rigid than the posterior half of the body which undulates rapidly during locomotion. The free end of the nylon leader was then circled back and sewn through the

bead and the tag secured in place. Free ends were then clipped off with a small pair of manicure clippers.

In most marking experiments, the left pectoral fin was removed, as a check in case of any tag shedding. The fin was clipped at its base with the manicure clippers. Such fin clipped fish were observed in aquaria and no deliterious effects were observed.

Description of Experiments

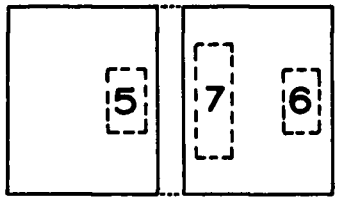
Sections of the beach where fish were marked will be referred to by bridge pillar numbers. The sections used for each experiment are shown diagrammatically in Figure 6.

Experiment 1. July 5, 1963, 18 fish marked, between pillars #9-13, beneath the bridge. Three different bead colours were used. Marked fish were replaced to where captured. Searching for marked fish was done over a subsequent two-day period.

Experiment 2. July 18, 1963, 32 fish marked, between pillars #10-12, beneath the bridge. Three different bead colours were used. Marked fish were transplanted to tidepools, 15-35 feet away from where captured. Observation for marked fish was done over a subsequent three-day period.

Figure 6. Diagrammatic representations of sections of study area used for each marking experiment. Each section (20' x 35' in the field) is denoted by solid line rectangles, within which, or adjacent to, the areas of original capture are shown in broken lines. Arrows show direction of transplantment, lack of arrows denotes a replacement experiment. Number of fish marked in each experiment indicated.

Expt.1.



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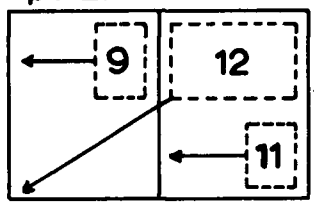

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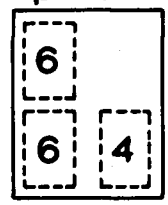

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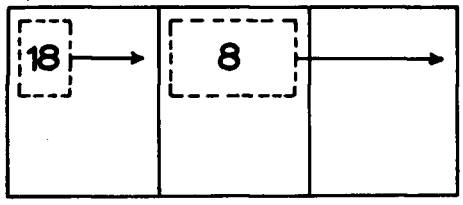

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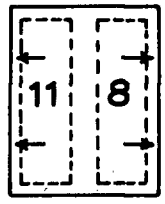

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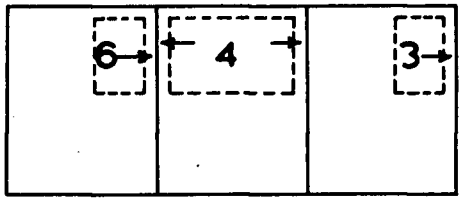

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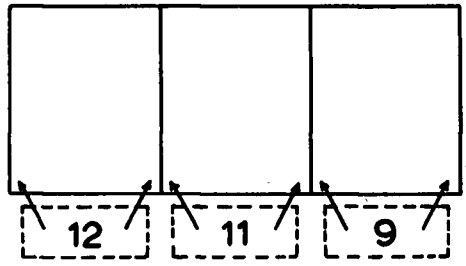

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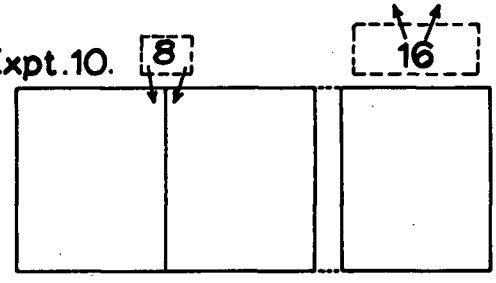

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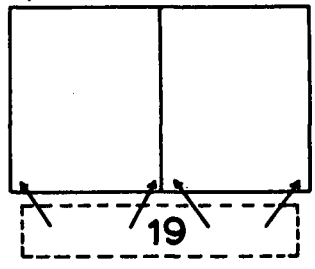

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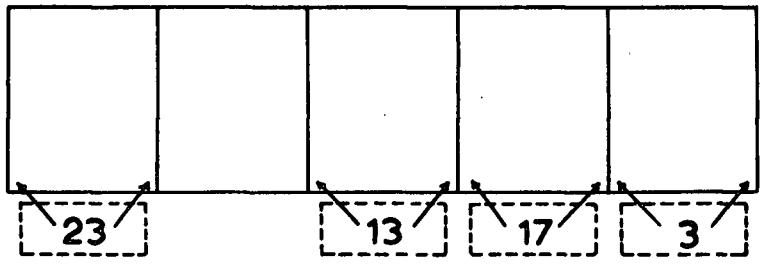
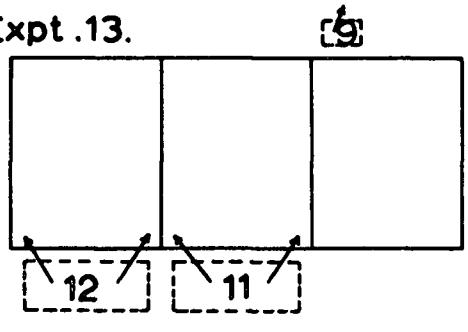
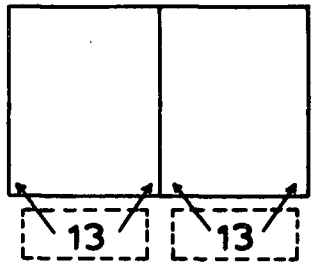


Expt.13.



Expt.14.



Experiment 3. August 2, 1963, 26 fish marked, between pillars #12-14, beneath the bridge. Two different bead colours were used. Marked fish were transplanted to tidepools, 15-35 feet away from where captured. Observation for marked fish was done over a subsequent two-day period.

Experiment 4. August 17, 1963, 16 fish marked, between pillars #9-10, beneath the bridge. Three different bead colours were used. Marked fish were replaced, but to tidepools, within 1-3 feet from where originally captured. Searching for marked fish was done over a subsequent two-day period.

Experiment 5. August 27, 1963, three fish were collected during the low tide, marked and replaced to where found when the area was just covered by water. Observation was then made from a boat until the fish could no longer be seen. Further observation was made during the next low tide that the area could be searched on foot.

Experiment 6. November 7, 1963, 12 fish marked, replaced, and the rocks painted. Observation was made during the subsequent high tide.

Experiment 7. January 11, 1964, 19 fish marked, between pillars #10-11, beneath the bridge. Two different

bead colours were used. Marked fish were transplanted to tidepools, 1-6 feet away from where captured. Observation was made on the following day.

Experiment 8. January 12, 1964, 13 fish marked, between pillars #11-14, beneath the bridge. Three different bead colours were used. Marked fish were transplanted to tidepools, 1-6 feet away from where captured. Observation for marked fish was not done until January 24, 1964, at which time the entire area from pillars #9-14 was searched.

Experiment 9. May 13, 1964, 32 fish marked, between pillars #2-5, adjacent to the bridge, west side. Three different bead colours were used. Marked fish were transplanted to very small tidepools, just beneath the bridge, a maximum distance of 18 feet but usually 6-10 feet. Observation was done over a subsequent three-day period.

Experiment 10. May 14, 1964, 24 fish marked, between pillars #10-11, beneath the bridge and between pillars #4-5, adjacent to the bridge, east side. Two different bead colours were used. The former mentioned fish were transplanted to a tidepool, a maximum distance of 15 feet. The latter fish were transplanted a maximum of 20 feet to a large draining body of water. Observation was

made over a subsequent two-day period.

Experiment 11. June 10, 1964, 56 fish marked, between pillars #1-6, adjacent to the bridge, west side. Four different bead colours were used. Marked fish were transplanted to very small tidepools just beneath the bridge, 6-10 feet away from where captured. Observation was made over a subsequent three-day period.

Experiment 12. June 11, 1964, 19 fish marked, between pillars #4-6, adjacent to the bridge, west side. Beads of one colour were used. Marked fish were transplanted as in latter experiment. Observation was done over a subsequent two-day period.

Experiment 13. July 7, 1964, 32 fish marked, between pillars #4-6, adjacent to the bridge, west side, and between pillars #3-4, adjacent to the bridge, east side. Three different bead colours were used. Marked fish from the west side of the bridge were transplanted as in the latter two experiments. Those on the east side of the bridge were transplanted to the draining area used in experiment 10, 8-10 feet from where captured. Observation was done over a subsequent four-day period.

Experiment 14. July 8, 1964, 26 fish marked, between pillars #2-4, adjacent to the bridge, west side.

Two different bead colours were used. Marked fish between pillars #3-4 were transplanted to the small tidepools just beneath the bridge. Those between pillars #2-3 were transplanted equally between the tidepools just beneath the bridge and the open water just west of where they were captured, both transplanting distances were of the same magnitude (about 6-10 feet). Observation was done over a subsequent three-day period.

Further observations for marked fish were made on July 22, 1964, July 24, 1964, August 4, 1964, August 5, 1964, August 7, 1964, September 3, 1964 and September 4, 1964.

Table XII outlines the marking experiments performed, showing the number of fish marked, and the number of returns of marked fish in actual numbers and percentages.

Replacement Studies

All markings of this type were carried out in 1963, and were confined to sections where only small numbers of fish could be located. Recaptured fish were classified as being either, in the areas of original capture, or in some other area. Percentage recapture has been expressed in two ways: as a percentage of the total number

marked, and as a mean percentage of the total number of experiments performed of this type (i.e., four replacement experiments, percentage recapture for each, mean percentage of four experiments).

Table XII. Type and dates of marking experiments performed; number of fish marked and return of marked fish.

Expt. No.	Date	Type of Experiment	No. Marked	No. Recap.	Percentage
1	July 5, 1963	replacement	18	3	16.6
2	July 18, 1963	transplant	32	3	9.4
3	Aug. 2, 1963	transplant	26	1	3.8
4	Aug. 17, 1963	replacement	16	1	6.3
5	Aug. 27, 1963	replacement	3	1	33.3
6	Nov. 7, 1963	replacement	12	6	50.0
7	Jan. 11, 1964	transplant	19	2	10.4
8	Jan. 12, 1964	transplant	13	0	0
9	May 13, 1964	transplant	32	5	15.6
10	May 14, 1964	transplant	24	2	8.3
11	June 10, 1964	transplant	56	15	26.7
12	June 11, 1964	transplant	19	4	21.1
13	July 7, 1964	transplant	32	4	12.5
14	July 8, 1964	transplant	26	3	11.5

Percentage recapture of marked fish is shown in Table XIII. The positions of the 11 recaptures are shown in this latter Table and in Table XIV, where a mean percentage recapture is shown for the four experiments performed. The percentage of marked fish found where originally captured was 100%.

Table XIII. Numbers and percentages (in parentheses) of marked fish captured, shown for positions of recaptures when found. All replacement experiments were performed in 1963.

	1963 Replacement Experiments	1963 Transplant Experiments	1964 Transplant Experiments	Combined 1963-1964 Transplant Experiments	Combined 1963-1964 Replace.-Transpl. Experi. Combined
No. marked	49	58	221	279	328
No. returns	11(22.5)	4(6.8)	35(15.8)	39(13.9)	50(15.2)
No. returns found:					
where marked	11(100.0)	2(50.0)	16(45.7)	18(46.2)	29(58.0)
in transplant area		1(25.0)	3(8.6)	4(10.2)	4(8.0)
other area		1(25.0)	16(45.7)	17(43.6)	17(34.0)

Table XIV. Percentage recapture of marked fish for each of 14 marking experiments performed. Mean percentage recapture shown in A, B, and C, for positions of recaptures when found.

Date of Marking	No. Recap.	Position of Recaptures Where Found: Where Marked	Transpl. Area	Other Area
July 5, 1963	3	3(100.0)		
July 18, 1963	3	2(66.6)		1(33.3)
Aug. 2, 1963	1		1(100.0)	
Aug. 17, 1963	1	1(100.0)		
Aug. 27, 1963	1	1(100.0)		
Nov. 7, 1963	6	6(100.0)		
Jan. 11, 1964	2	1(50.0)		1(50.0)
Jan. 12, 1964	0			
May 13, 1964	5	4(80.0)		1(20.0)
May 14, 1964	2	2(100.0)		
June 10, 1964	15	3(20.0)	2(13.3)	10(66.6)
June 11, 1964	4	2(50.0)		2(50.0)
July 7, 1964	4	2(50.0)		2(50.0)
July 8, 1964	3	2(66.6)	1(33.3)	

A. Replacement experiments.

Mean percentage of marked recaptures found:

where marked	------	100.0
other area	------	0

B. Transplant experiments.

Mean percentage of marked fish found:

where marked	------	53.69
in transplant area	------	16.29
other area	------	29.99

C. Replacement-Transplant experiments combined:

Mean percentage of marked fish found:

where marked	------	67.17
in transplant area	------	11.28
other area	------	20.76

Transplant Studies

Markings of this type were carried out in 1963 and 1964. Recaptured fish were classified as being in the areas of original capture, in the areas to which they were transplanted, or in some other area. Percentage recapture is expressed in the same manner as presented in the replacement studies.

Percentage recapture of marked fish is shown in Table XIII, with the experiments performed in 1963 and 1964, shown separately and combined. The positions of the 39 recaptures are shown in this Table and in Table XIV, where a mean percentage recapture is shown for 10 transplant experiments performed. The percentage of marked fish found where originally captured was 46.2%; a mean percentage recapture of 53.69%.

Replacement-Transplant Studies Combined

The positions of the 50 recaptures are shown in Table XIII, and in Table XIV, where a mean percentage recapture is shown for the 14 experiments performed. The percentage of marked fish found where originally captured was 58.0%; a mean percentage recapture of 67.17%.

Homing vs Non-Homing

Marked fish located in the areas of their original capture can be referred to as "homing" fish. All other recaptures of marked fish, whether in the areas to which they were transplanted, or located in other areas, can be referred to as "non-homers" or "strays".

Incidence of Non-Homing

Four fish (8.0%) were recaptured in the areas to which they were transplanted (Table XIII). These fish had either not moved during the subsequent time between observations, or if they had moved, returns were made to the same areas.

Seventeen fish (34.0%), a mean percentage of 20.76%, accounted for recaptures located in other areas (Table XIII). This incidence of straying can be considered distinct from the latter, in that a definite movement away from where originally marked and from where transplanted, was executed, with no indication of any return during the time between observations.

Time Elapsed to Recapture and Occurrences of Multiple Recapture

Search for marked fish was carried out two to three days subsequent to marking (except for one replacement study, where it was made on the high tide immediately following the low). All marked fish recaptured from replacement experiments were located during this time period. With the replacement experiments there were no instances of multiple recapture of marked fish.

Recaptures from transplant markings were taken from one to thirty-one days subsequent to marking. Twenty-two fish were located at some time in the three-day observation period directly after marking, one fish was found 15 days after marking and the remaining 16 fish were located 26 to 31 days subsequent to marking.

Four fish from the transplant experiments were recaptured for a second time. Another fish was seen for the second time, but escaped recapture. The dates of each recapture and the positions of these fish when recaptured, are shown in Table XV.

In three of five occurrences of multiple recapture, the fish were located for the second time in the area occupied on their first recapture, although only one fish was

Table XV. Cases of multiple recapture of individual marked fish, with dates of each recapture and positions when recaptured.

Date of Marking	Date of First Recapture	Date of Second Recapture	Remarks
June 10, 1964	July 9, 1964	July 22, 1964	Recaptured away from where originally marked, but same area each time.
July 7, 1964	July 9, 1964	July 10, 1964	Recaptured where originally marked each time.
July 7, 1964	July 10, 1964	July 11, 1964	Recaptured away from where originally marked, but same area each time.
July 8, 1964	July 9, 1964	July 11, 1964	First recapture where originally marked, second in other area.
June 10, 1964	July 10, 1964	Aug. 4, 1964	Was seen only for the second time, movements cannot be traced.

located in the spot of its original capture, each time. As with all recaptures from transplant experiments, recaptured fish were replaced to the areas of original transplant.

Extent of Movements

Results of transplant experiments show that Anoplarchus is definitely carrying out movements during periods of tidal coverage. Indications are, however, that these movements are restricted. Straying of fish from their areas of original capture was observed to be of two types; fish remaining in their areas of transplant, or, fish straying to other areas. Fish located in their areas of transplant had either remained in these areas between observation periods, or had circulated and returned to these areas. The former assumption seems very unlikely, in that two of the four fish found in such areas were located a long time after the three-day observation period immediately following marking. It appears therefore that these fish had returned to the areas after having moved during tidal coverage. The transplant areas were located at a range of 6 to 35 feet from the areas of original capture.

Those fish recaptured in other areas were located at a distance of 6 to about 75 feet, from the areas of original capture. Only a very small number (3 fish) however,

were found at a distance greater than 50 feet.

Both instances of straying, therefore, indicate a rather limited movement.

Marked fish recaptured from replacement experiments indicate a strong tendency to remain in a given area. Recaptures from these experiments were all found within the three-day observation period immediately following their marking. Straying was not observed, all fish were found within the areas of original capture.

Territoriality

Observations of the distribution of Anoplarchus made during marking experiments and while collecting specimens for other parts of the study, point out seasonal trends in distribution of the species over the area. At times of the year preceding breeding, it is common to find as many as six or more individuals beneath the same rock. Random sampling of fish for collections has shown that there is no sexual or individual segregation at this time.

During the breeding season, including the period of pair formation just prior to spawning, segregation becomes obvious. At this time it is uncommon to see more than the one pair of sexes beneath the same rock, although very large

rocks may yield as many as two such pairs during the period of pair formation just prior to spawning. Later, when egg masses were observed, an individual rock yielded only a single egg mass. More than one egg mass was never found beneath a single rock.

It appears from these observations, that Anoplarchus exhibits both home-range and defended territoriality, the form exhibited depending on the particular season involved. At times other than the breeding season, the territory would be of the home-range type, as there is no indication on the part of the individual to exclude others of the species from the area inhabited. During the breeding season, however, definite segregation is apparent, with only sexual pairs sharing a small area. It seems likely that an active defence must be present to maintain this situation.

Discussion

The possession of a homing behaviour is considered a mechanism by which intertidal fishes are safeguarded against being stranded in some unfavourable situation. Thus, homing in fishes such as the tidepool inhabiting sculpins (Williams, 1957; Eastman, 1962), would ensure that the return of the animal to a pool which was permanent; its failure to do so could result in death.

Williams (1957) considered homing and straying with reference to individual tidepools, but points out that although the pool is a convenient unit to deal with, there is no reason to believe that it is the "pool" as a hydrographic unit to which the fish homes. Considerable likelihood of some localization of individuals within large pools was noted by the author. As Gerking (1959) stressed, the site named "home" is not as important as the fact that the fish elects to return to a place where he has been previously instead of to some other equally probable place.

Recognition of the home area would require accurate spatial familiarity, with active avoidance of being left in any, but that particular area by the outgoing tides. For Anoplarchus, a species which is directly associated with the substrate of rocks and vegetation, this would call for a great rememberance of the route or routes to the home area and an active seeking of this area on outgoing tides.

Results of the marking experiments did not indicate a strong tendency to home, although both types of experiments did indicate movements of Anoplarchus to be somewhat restricted. The locality sense of animals may take a variety of forms, some of which bear resemblance to the classic type of territoriality (defended area), but others differ in that the animal shows no tendency to exclude

others of the species from its restricted area of movement. It is this latter form which is termed home range or home-range territory (Dice, 1952; Gerking, 1959; Etkin, 1964).

It appears, based on the results of the marking experiments and observations made of the distribution of the species on a seasonal basis, that Anoplarchus displays both forms of territoriality. Close association of individuals preceding spawning, with apparent lack of any tendency of exclusion, indicates that at this time the individuals are sharing home-range territories. However, during the breeding season, a definite contrast to the latter situation is shown. At this time individuals are highly segregated, both spacially and sexually, into isolated breeding pairs. The isolation of such breeding pairs indicates that each pair may be maintaining a small breeding territory.

A territory of the defended type is maintained by aggressive actions of the territory holder. Behaviour of two breeding pairs was observed under laboratory conditions. The behaviour observed will be discussed in detail in a later section on reproduction, but it should be pointed out here that aggression was displayed between members of a breeding pair, both before and after spawning. Before spawning, aggression was shown by the male only. Following spawning however, the female warded off any advances of the

male towards that part of the tank where she was providing parental care to the eggs. Such a behaviour displayed in the field would serve to ward off the sexual partner and any other intruders which may happen to infringe upon the nesting site, and thus maintain the established breeding territory. Guarding females were observed in the laboratory to provide such care to eggs up to the time that they hatched.

Thus, the male likely defends the breeding territory until spawning occurs. After spawning, the female takes over and defends the territory until the eggs have hatched.

REPRODUCTION

Sexual Dimorphism

Early descriptions of the colouration of A. purpurescens although sometimes quite extensive, failed to point out the sexually dimorphic nature of the colouration. Gill (1861) in his original description of the species, stated the colour to be a dark purple. Jordan and Evermann (1898) gave a fairly detailed and extensive account of the colouration and pointed out variation in colouration between individuals. However, they did not indicate the sexually dimorphic nature of the colouration. In their description of the eggs and nesting habits, Schultz and DeLacy (1932) mentioned that the sexes of Anoplarchus were coloured differently, but their account of the differences was extremely brief. Clemens and Wilby (1961) attempted to show the dimorphic nature of the colouration between the sexes and the extent of variation between individuals, but as with Jordan and Evermann, their account was not extensive.

In the description to follow, colour will be described only as it emphasizes dimorphism between the sexes. The description is based on both living and preserved specimens.

The general body colouration of the male is usually darker and less interrupted in its distribution on the body, than that of the female. Colour is highly variable; light gray to dark gray, with olivaceous overtones; brown to dark brown, with or without reddish overtones; purple to almost black. Regardless of colour shown, colouration of the male is uniformly distributed and lacks the usually highly mottled quality of the female. Colour of the female is not as variable as the male; light to dark gray, with olivaceous overtones, marked with brownish gray reticulations; dark brown, less reticulated, lacking reddish overtones. The belly is pale. Speckling of the body is more subtle in the male due to its usual darker colouration. Cockscomb and under-surface of the head are pale, rather yellowish and devoid of any speckling or mottling in the male. The female, in direct contrast, shows a highly speckled and mottled head, on both the lateral and undersurfaces, especially marked on the jaws and throat. This latter feature of colouration enables one to quickly identify the sex of preserved specimens.

With the approach of the breeding season, the most striking features of the sexually dimorphic nature of the colouration become obvious. The male at this time develops a bright orange to red colouration on its fins. The anal and pectoral fins become bright orange, somewhat more

striking on the anal fin. The caudal and dorsal fins show a reddish colouration, usually more pronounced on the caudal fin. The non-breeding male shows a similar colouration but more subtle and usually confined to the anal and pectoral fins. Fins of the female are highly speckled and lack bright colouration. The dorsal fin shows distinct grayish to white blotches, which extend ventrally on the dorsal part of the back.

Along with the differences in colouration between the sexes at this time of the year, in both sexes the cockscomb enlarges with sexual maturity. This structure of the male becomes larger than that of the female in both height and width.

The females average a larger size than the males. In all but two of the 13 samples collected for length frequency, the mean length of females was greater than that for males. Among 269 fish collected, the longest female was 128.0 mm in standard length, and the longest male, 123.5 mm. The mean length of females (157 fish) was 97.05 mm, and of males, 95.01 mm (112 fish).

Gonad Measurements and Fecundity

Methods

Sexually mature fish, distinguished on the basis of granular ovaries and enlarged, opaque testes, were selected from the September, 1963, December, 1963 and January, 1964, samples. The spawning egg masses examined were obtained on February 9, 1964, and February 12, 1964. The masses were fixed in 10% formalin and then placed into 40% isopropyl alcohol.

Gonad measurements were made with a pair of draftman's dividers and a small metric scale. All measurements were recorded to the nearest one-tenth of a millimeter. Sixteen males were examined, over a range in standard length of 83.0 to 123.5 mm. The testes were measured for length of both left and right lobes and greatest overall width. Ten females were examined, over a range in standard length of 89.0 to 128.0. The ovaries were measured for length and greatest width. The measured gonads were then placed into numbered vials.

Actual egg counts were performed on one ovary and one egg mass. All remaining counts were estimated using the Von Bayer method (Von Bayer, 1908).

To obtain the actual counts, the ovary or egg mass was broken with a pair of dissecting pins and the eggs separated. Tallying of count was done with a small hand recorder. Breaking up of egg masses frequently caused eggs and their corresponding yolks to become separated. In such cases, yolks only were counted.

Average diameters of eggs from the ovaries and masses were obtained by the Von Bayer method. Consultation of the table giving number per quart for eggs of various diameters was then done and this figure converted to number per cubic centimeter by dividing number per quart by 946.4. Volumetric displacement of the ovary or egg mass was then determined (in water) and the figure obtained multiplied by the number of eggs per cc, to obtain the estimate of number of eggs in the ovary or egg mass.

Results

Measurements of Testes

The lengths for each lobe and greatest width of the entire structure, are shown for each of the 16 males studied, in Table XVI. In each individual examined the left lobe of the testis was slightly longer than the right. The left lobe ranged in length from 8.4 to 17.8 (mean 12.6)

mm and the right lobe from 7.1 to 17.0 (mean 11.3) mm. This difference is due primarily to the anatomical arrangement of organs in the coelomic cavity. In Anoplarchus the urinary bladder lies to the right side in the body cavity. The left lobe of the testis extends posterior and adjacent to this structure, whereas, the right lobe is inhibited from doing so, and ends at the tip of the bladder.

Table XVI. Gonad measurements; 16 testes and 10 ovaries.

Testes				Ovaries		
	Length					
Standard Length	Left Lobe	Right Lobe	Greatest Width	Standard Length	Length	Greatest Width
83.0	8.9	8.4	3.3	89.0	21.0	8.9
90.0	13.5	11.2	5.4	91.5	18.4	7.1
91.8	10.0	8.0	4.5	92.0	20.7	8.9
94.8	14.5	13.8	6.8	106.5	20.1	9.5
95.0	16.8	15.5	5.4	109.0	23.0	10.3
95.5	11.7	10.7	5.2	109.2	23.6	10.8
98.3	8.4	7.1	3.8	111.5	25.1	11.9
101.0	10.0	8.6	5.1	117.0	27.0	12.3
102.0	9.8	9.0	5.0	120.0	28.0	11.4
104.0	15.5	12.8	6.9	128.0	25.8	10.1
105.0	13.1	11.5	6.9			
105.2	11.1	10.6	5.7	Mean	23.3	10.1
109.9	17.8	17.0	6.5			
115.0	12.5	10.9	5.0			
118.0	13.9	12.2	6.1			
123.5	13.6	12.2	4.7			
Mean	12.6	11.3	5.4			

Measurements of Ovaries

The lengths and greatest width of the structure, are shown for each of 10 females studied, in Table XVI. The ovary is a partially bilobed structure; differences in lengths of the two lobes did not appear to warrant differentiation in the measurements. Ovaries ranged in length from 18.4 to 28.0 (mean 23.3) mm and in greatest width from 7.1 to 12.3 (mean 10.1) mm.

Egg Measurements

The average egg diameters obtained for each of the 10 ovaries and two egg masses studied, are shown in Table XVII. Unfertilized eggs from the ovaries ranged in average diameter from 0.787 to 0.965 (mean 0.864) mm and fertilized eggs from the masses from 1.270 to 1.448 (mean 1.372) mm.

Egg Counts

Actual and estimated numbers of eggs for the 10 ovaries and two egg masses studied, are shown in Table XVII. Counts from ovaries ranged from 2,001 to 3,183 (mean 2,738) eggs and from the masses, 2,288 to 3,082 (mean 2,685)

eggs.

Table XVII. Fecundity; egg counts of 10 ovaries (A.) and two egg masses (B.). Actual counts indicated by asterisk.

	Standard Length	Ave. Dia.	No. of Eggs
A.	89.0	0.889	2,001
	91.5	0.838	2,387
	92.0	0.864	2,183
	106.5	0.787	2,880
	109.0	0.838	2,984
	111.5	0.889	3,002
	114.0	0.838	3,183
	115.0	0.889	3,093*
	117.0	0.914	3,065
	120.0	0.965	2,606
B.	119.5	1.448	3,082*
	---	1.270	2,288

Discussion

In this species, it is clear that the entire egg-production of each female is being concentrated into a single spawning act. This is evident from the close similarity of counts of unfertilized ovarian eggs and fertilized eggs of the laid masses, and also from observations of spawning results in the laboratory and subsequent gonadal examination of the fish involved. Spawned fish (male and female) were

found to be completely "spent", (gross examination only was performed) and could not therefore have spawned again for a year. This condition appears common for northern fish species (Qasim, 1955).

The mean number of eggs obtained for the ovaries was 2,738; and for the egg masses, 2,685. Schultz and DeLacy (1932) reported a mean number of 1,613 eggs, for six unspawned females, with a mean standard length of 88.0 mm, as compared with a mean standard length of 106.6 mm, in the present study. Gudger (1927) reported only 686 eggs in a mass laid by Pholis gunnellus.

The number of eggs plotted against length of female, (Figure 7) produces a straight line relationship, with number of eggs increasing as size of female increases. Data were used from the study of Schultz and DeLacy as well as the present study, for construction of the graph.

The mean average diameter of unfertilized eggs was 0.864 mm, and for fertilized eggs, 1.372 mm. Schultz and DeLacy reported a range in diameter of unfertilized eggs of 0.693 to 1.112 mm, a mean was not shown but it was stated that it is about the same size as the diameter of the yolk material of fertilized eggs; a range in the latter of 0.819 to 1.070 mm, was shown. They reported an average diameter of fertilized eggs of 1.441 mm. Discrepancies

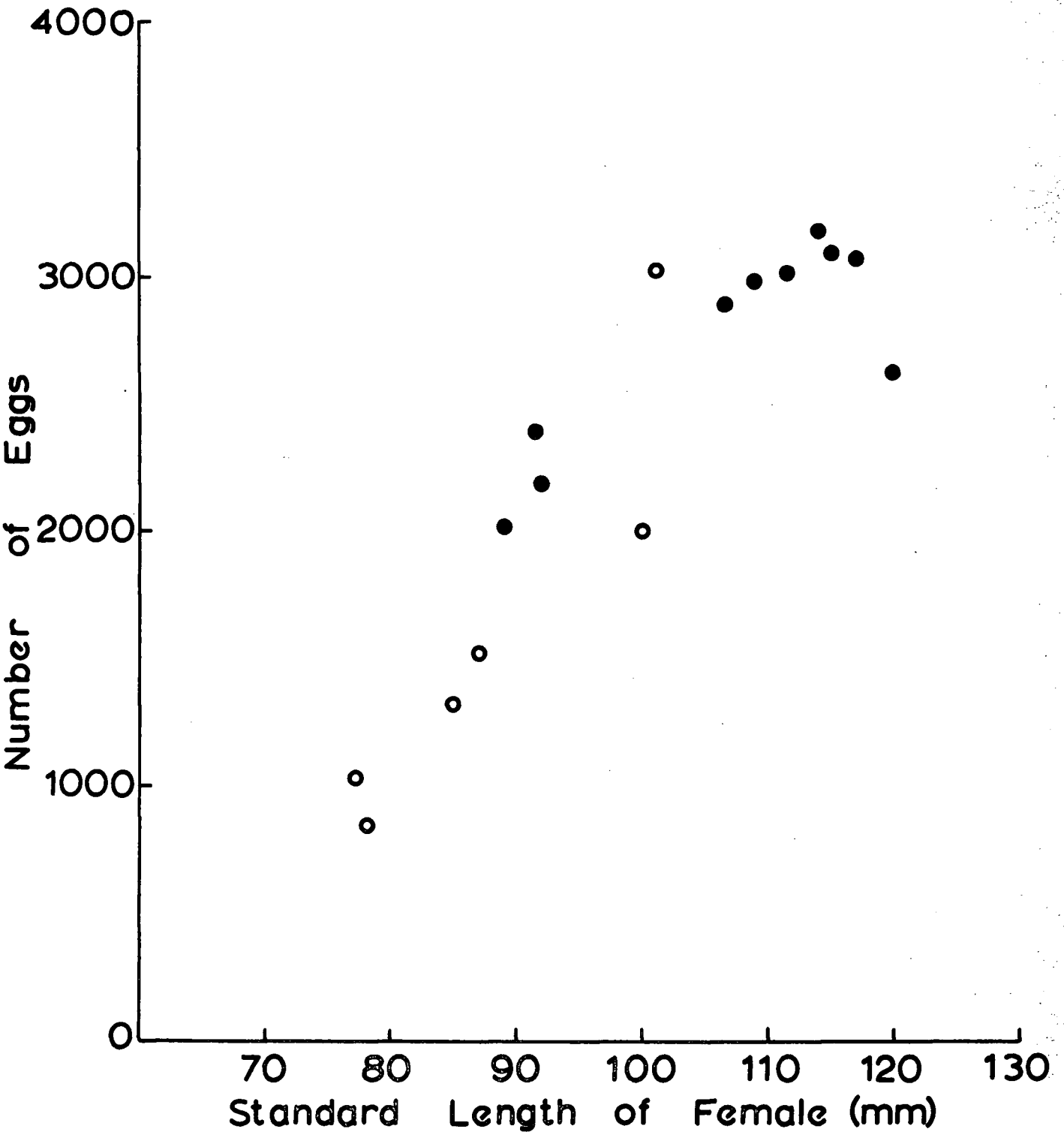


Figure 7. Graph showing relationship of number of eggs produced to length of female. Unenclosed dots represent data gathered by Schultz and DeLacy (1932).

between the two studies are probably related to differences in size ranges examined and sample sizes.

The fertilized eggs of Anoplarchus are about the same size as those of Blennius pholis, which are 1.4 mm, as reported by Lebour (1927), but smaller than the eggs of Pholis gunnellus, which average about 2.0 mm in diameter (Gudger, 1927). Size of the egg does not appear to correlate with size of fish or number of eggs produced.

Within the small sample of males studied, there did not appear to be any correlation between size of fish and length or width of the testes. This lack of correlation may be due to the small sample size and/or to different degrees of "ripeness".

The length and width of the ovary however, does appear to correlate with size of the female.

Hatching of Eggs and Rearing of Young in the Laboratory

In 1964 one attempt was made to hatch eggs of Anoplarchus. Four egg masses were collected from the study area on February 12, 1964, and placed into a well aerated, but non-circulating, tank of sea water. Temperature was controlled only by insulating the entire set-up with sheets of glass-wool. The tank was kept in darkness.

During the breeding season of 1965, further attempts were made to hatch eggs and also observe spawning behaviour. On January 16, 1965, a guarding female and her egg mass was placed into a three-gallon aquarium. The aquarium was equipped with a cooling tube (glass tubing with running cold tap water), aeration, sand-covered bottom and a few small stones to provide a shelter. The tank was kept covered, allowing only a minimum of daylight to enter. Over the duration of the observation period, water temperature fluctuated between 10° to 12°C.

As well as the female and her egg mass, two pairs of fish were also collected on the same day. The purpose of their collection was for attempts to observe spawning behaviour.

Results

The 1964 attempt to hatch eggs was unsuccessful. The egg masses which were at varying stages of development when collected (one mass was "eyed", the others not), survived for 11 days. One mass reached a stage very close to hatching, as witnessed by observation of movements within the eggs, but hatching did not occur. Fluctuating temperature may have been a factor in the subsequent death of the eggs.

Attempts made in 1965, under controlled conditions, were successful. Two hatchings were observed; one from a spawning of one of the pairs of fish in the lab and the other from the egg mass and female collected.

Female and Egg Mass

Continual parental care was provided by the female, from the time of placement into the aquarium, to the time of hatching. The observed behaviour of the female will be described in a later section.

The egg mass at time of collection was "uneyed", and reached the eyed stage by the fourth day of incubation. On the twelfth day of incubation, the mass possessed a golden sheen, due to the eyes of the embryos within. The first hatched fish was observed on January 29, 1965, the thirteenth day of incubation. Further hatching was prolonged. Only about 12 fish were observed until the morning of February 3, 1965, when the aquarium was clouded with hatched larvae. The female at this time was observed to be out from the shelter of stones and was removed and preserved for subsequent examination.

Young were removed from the aquarium at 24-hour intervals, over the 18-day period from first hatching to

death of the remaining young.

Laboratory Spawned Pair of Fish

The pair of fish was placed into a five gallon aquarium on January 20, 1965, equipped in the same manner as the tank previously described. Instead of stones for a shelter, an abalone shell was placed in one corner of the tank. Water temperature was cooler, and over the duration of observations fluctuated between 7° to 9°C. The fish spawned, unfortunately without personal observation of the spawning act, on February 23, 1965. The male was removed from the aquarium. Observations made of their behaviour prior to spawning will be described in a later section.

The egg mass was located beneath the shell and could be observed only by lifting the shell and disturbing the guarding female. Actual observations of the eggs over the incubation period were therefore kept infrequent. The female provided continual parental care.

The first hatched larvae were observed on March 11, 1965, the sixteenth day of incubation. Hatching did not appear to be prolonged as shown by the previous observations. When the first larva was observed, the tank was clouded with young. The female was removed at this time

and preserved.

Hatched fish were not sampled, as the previous hatching provided a number sufficient to describe the young.

The young survived to March 19, 1965, eight days after hatching. On this day, the air supply to the tank was observed to be off and therefore may have been one of the causes contributing to the death of the young.

Description of the Spawned Out Condition

The two females had standard lengths of 118.0 mm (female and egg mass) and 113.3 mm (female of pair #1). The latter female spawned with a male of 133.8 mm standard length.

All fish were found to be completely "spent", except for a very small number of ova remaining in the ovaries.

The bellies of both sexes were shrunken and flattened, and "worn" of the outer layer of pigmented skin in the females. The sides of the bodies of females, adjacent to the bellies, were wrinkled, quite noticeably before their preservation. The gonopore region was pinkish, rather "raw" in appearance.

Description of Young

The newly hatched larva is translucent and varies from 7.4 to 7.6 mm in total length. At several positions on the body, the larva is pigmented with melanophores, constant in their disposition. An oval yolk sac is present, with an oil droplet anterior in position (Figure 8).

The head is free of pigmentation. A pair of large chromatophores are present on the antero-lateral surface of the yolk sac, immediately in front of the oil droplet. Dorsal to the sac, there is one (may be absent) large chromatophore on the gut tube. Along the ventral mid-line of the body, running from the anterior end of the yolk sac to a point just ahead of the anal papilla, there is a row of 10 to 14 large chromatophores. Two to three large widely-spaced chromatophores are present ventrally on the gut tube, from the yolk sac to the anal papilla. Two large chromatophores are situated on the lateral surfaces of the anal papilla, and a pair of equal size median to the latter, at the base of the papilla. From a point just posterior to the anal papilla, a row of 36 to 47 small chromatophores runs along the ventral mid-line of the body to a point near the caudal peduncle. On the caudal peduncle, separated from the latter, four to six chromatophores are present.

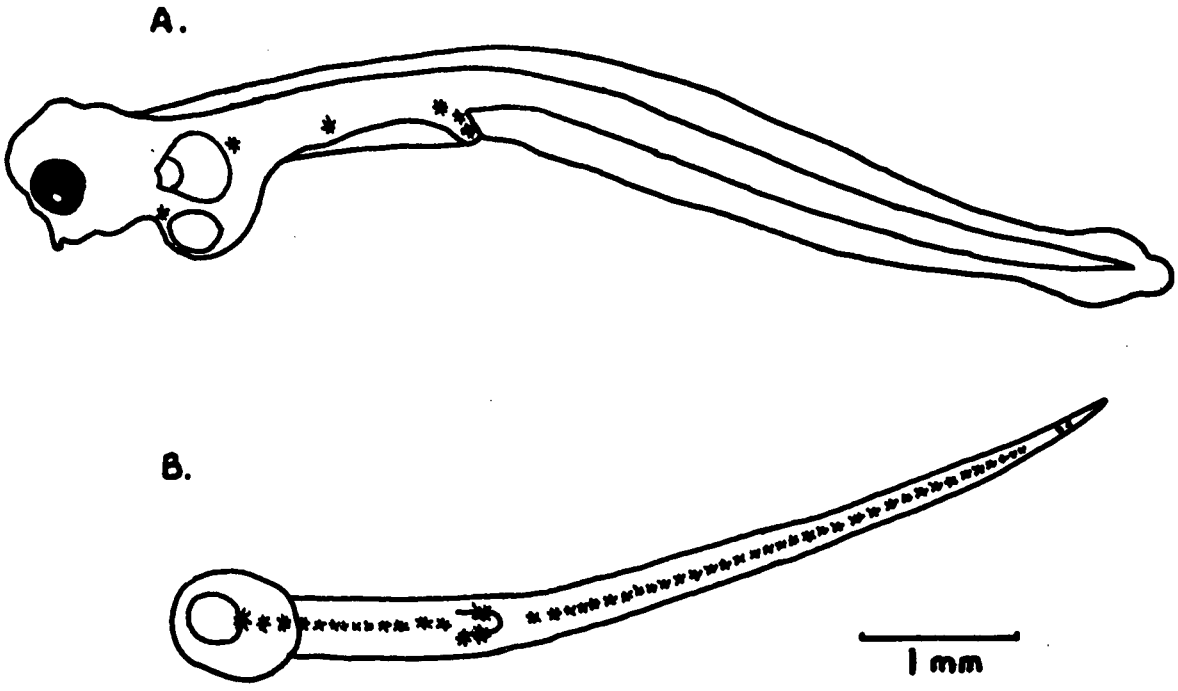


Figure 8. Newly hatched larva (less than 24 hours old); 7.4 mm total length. A. Lateral view of left side; B. Ventral view, from anterior tip of yolk sac, to tail.

The fin-fold is continuous, beginning dorsally from a point marking the vertical anterior extent of the yolk sac, and ventrally from the posterior end of the yolk sac. The fold widens over the trunk, and narrows over the caudal peduncle, both dorsally and ventrally.

Body colour of preserved specimens is a pale cream. Surface of the eyes are a silvery black.

Forty-eight hours after hatching, the larvae average 7.85 mm in total length. The yolk sac with enclosed oil droplet is still present, although reduced considerably in size. No changes were observed in disposition or number of chromatophores.

By ninety-six hours, the larvae average 8.05 mm in total length. The yolk sac at this stage is very small. The chromatophores along the ventral mid-line of the body, from the anterior end of the yolk sac to a point just ahead of the anus, had enlarged and become rather diffuse; a count of 17 was obtained for one individual, an increase of three over the highest count obtained for a twenty-four hour larva. Other chromatophore counts and disposition were the same as the latter stage described.

By five days after hatching the larvae averaged 8.18 mm in total length and the yolk sac is completely

absorbed.

Twelve days after hatching the young average 8.50 mm in total length. Chromatophore disposition is still similar to the latter stage described, but counts of those on the ventral mid-line of the body could not be made because of their enlarged and diffuse nature. Other chromatophore counts were the same as before.

One fish of thirteen days of age showed only one difference to the latter stage described; an increase by one, in the chromatophore count of those present ventrally along the gut tube, between yolk sac and anus.

Further changes observed included enlargement of the mouth and jaws, opercular bones and branchiostegals, and the pectoral fins. The fin-fold of the oldest individual was still continuous.

Discussion

Hatching times of 13 and 16 days, were obtained for temperatures of 10° to 12°C and 7° to 9°C, respectively. In the first hatching (female and egg mass) the time of appearance of the first hatched larva to complete hatching, was prolonged. The first larva was seen on the thirteenth day of incubation but hatching was not complete until the

eighteenth day. The second hatching (laboratory spawned fish) did not show this prolongation in the hatching of young; however, the actual time of spawning was not critically determined, and the estimate of sixteen days to hatching may be somewhat low. The temperature of this set-up was lower than the previous developmental temperature. Pholis gunnellus was reported to have a period of incubation of 42 to 70 days, at about 6°C (Ehrenbaum, 1904).

The length of hatched larva of Anoplarchus was 7.4 to 7.6 mm which is smaller than that reported for Pholis gunnellus by Ehrenbaum (1904), who stated the larva to be about 9 mm at hatching. It is however, much larger than the clinid, Paraclinus marmoratus, which is only 4.1 mm at hatching (Breder, 1939).

The young of Anoplarchus show marked positive photoaxis. A light placed at one end of the aquarium brought the larvae to the surface at this end. They were also observed to gather at the surface at the back of the tank where daylight from a window behind entered the aquarium. This positive phototactic response appeared to lessen after three days of age, and by five days, the young appeared negatively phototactic, and would remain close to or on the bottom. On cleaning of the aquarium subsequent to the death of the young, the largest percentage of dead fish were

located beneath the shelters provided. This tends to confirm that the young were negatively phototactic at this stage.

This light reaction may have considerable significance to the habits of the young in the first few days of life. Possession of a positive phototactic response would bring the hatched fish out from beneath the rocks and into the currents when locomotory powers were not developed to any great degree, thus becoming an element of the plankton. Once the positive response to light was lost, the larvae would seek the bottom and dispersal would depend more on the individual once locomotion was developed to a higher degree, rather than on currents.

Because of failure to keep larvae alive for any length of time in the laboratory, and the lack of knowledge of their movements during the first few months of their life in the field, nothing further is known about the development and metamorphosis of larval fish.

The young of the 1964 breeding season were first found in the intertidal area on June 11, 1964. At this stage they measured between 29.0 and 30.8 mm standard length. All appeared adult-like in form, with small cockscombs and were fully pigmented. Still smaller fish of 25.5 and 27.0 mm, were collected in July and August of 1964.

The first young located (June sample) were found beneath rocks in the kelp beds of the low-intertidal zone. In later samples the young were located over habitat in both the mid- and low-intertidal zones. The latter data suggests that there had been a movement of young from the sub-tidal into the intertidal zone, with a progressive movement up the beach. This movement to the intertidal area appears to take place when the young are 25 to 30 mm in length.

Breder (1941) stated the larvae of Paraclinus marmoratus to be positively phototactic at hatching, but remained so for a maximum period of only one day, then sought the bottom. He concluded that they had a planktonic existence for a very short time. In contrast, Lebour (1927), reported that the young of Blennius pholis and B. gattorugine, remain in the plankton up to 18 mm and 20 mm or more in length, respectively. Young of B. pholis of 25 mm were found in small rock pools near high water mark.

Evidence as witness by the phototactic responses shown by Anoplarchus young, suggests that they are planktonic elements for at least three to five days but then are negatively phototactic and seek the bottom. Thus, they are similar to the young of Paraclinus marmoratus, but maintain the positive phototactic response for a longer period of

time. It would appear that migration of young to the intertidal area is accomplished by locomotion and not by a more passive planktonic migration.

Behaviour Associated with Courtship, Parental Care and Between the Sexes Subsequent to Spawning

Courtship

As previously stated, two pairs of fish were brought into the laboratory in an attempt to observe courtship and spawning. The first of such pairs (Pair #1) was placed into an aquarium on January 20, 1965. The fish were not fed. Daily observations were made as to the activity of the fish.

An abalone shell was placed at one end of the tank, to provide a shelter, as well as a possible site for the spawning. An observation in the field of an egg mass being guarded in a large butter clam valve indicated that Anoplarchus like certain other blennioid fishes, does utilize such structures as spawning sites. Schultz and DeLacy (1932) reported the finding of an egg mass of Anoplarchus in a clam shell, while Gudger (1927) and Ehrenbaum (1904) reported the finding of eggs of Pholis gunnellus in oyster shells.

The pair upon introduction into the aquarium

immediately situated beneath the shell and during the majority of observations, were found in such a position.

The fish were noted to be very inactive until January 30, 1965, when both sexes appeared to be rather restless. The pair was observed with the aid of daylight from an above window, for two hours. Observation was made through a small window cut into the cardboard surrounding the tank, at a distance of about two to three feet.

Pair number two was set up on March 1, 1965. The female was bulging with eggs and first observations appeared to indicate a readiness to spawn. The sexes were kept separated between observations by a clear partition of glass, in an attempt to eliminate unwitnessed spawning.

Upon first introduction to the tank, the fish were fed live earthworms. Up until this time the fish had only been fed sparsingly, on frozen adult brine-shrimp. Earthworms were accepted readily and none was regurgitated.

The tank was set up firstly without a shelter, but later an abalone shell was added.

All observations were made in the evenings, and therefore, a lamp had to be used for illumination. A cardboard box with slits through which one could observe was placed over the aquarium and the lamp set at one end, with

the light directed to the side. Such an arrangement allowed only enough light to enter to observe the movements of the fish, not quite sufficient however, to describe in detail colour changes. The fish were allowed 10 to 15 minutes to acclimatize to the light before observations were commenced.

Observations were made over 15 periods, each period varying in length from 1 1/2 to 3 1/2 (mean 2 1/2) hours. If the fish showed any indications of awareness of the observer, observations were curtailed for a few minutes. With each period, observations ceased when the fish were no longer active.

Results - Pair Number One

This pair was observed for only two hours. As with Pair #2, the female was the most active sex. Her movements were strictly confined to the area adjacent to the shell, repeatedly swimming beneath and over the shell, frequently perching on top.

The male in contrast, was rather quiet, remaining near and usually partly under, the shell. Occasional bursts into active swimming at the back of the tank however, did occur.

One approach of the female towards the male, while

the latter fish was beneath the shell, was met with two strong bitings to the head. The female did not swim away but moved in closer to the male. Observations of Pair #2 showed that such agonistic behaviour by the male usually elicited fanning by the female. No such fanning behaviour was observed by Pair #1.

Several other approaches were made by the female to the side of the male. No further displays of agonistic behaviour were observed and the male did not appear to respond to the closeness of the female in any characteristic manner. His usual reaction was to remain motionless or slowly move away.

Similar to Pair #2, movements of either sex were closely watched by the opposite sex.

Subsequent to January 30, 1965, frequent checks were made as to the activity of the fish but no observations indicated a readiness to spawn.

On February 23, 1965, an egg mass was found beneath the shell, with the female coiled and fanning. The spawning was unwitnessed.

Results - Pair Number Two

The first observation period (2 hours) was on

March 2, 1965. The fish were very active and the different behavioural patterns observed were found, when subsequent observations were made, to represent almost the whole spectrum of behavioural patterns observed over the entire 15 observation periods. The behaviour observed will be described in detail and can be considered typical of all behaviour observed. Data gathered from other observations will be used to supplement and quantify the first period observations.

Upon removal of the partition, the sexes almost immediately came together. The approach by each sex was about equal and elicited an erection of dorsal and anal fins of both fish. The pair was together for only a few seconds. Investigative behaviour was then shown, with both fish moving about parts of the tank where their movements were previously inhibited due to the partition. Movements of either fish were keenly followed by the other, both visually and physically.

Frequent approaches of one sex to the other were observed and for the most part these advances were made by the female. In approaching the male, a characteristic pose was assumed; body held somewhat U-shaped, undulated slowly, bringing about a somewhat sideways movement towards the male and ending with the lateral surface against the length

of the male's body. With these movements dorsal and anal fins were fully erected and caudal fin expanded. Colouration was very light.

Such advances by the female usually elicited a strong aggressive attack by the male; a biting to her head or pectoral area. These bitings were sometimes repeated several times. In one observation period of two hours duration, the male was observed to bite the female a total of 10 times, in quick successions of two or three bitings at a time. With other approaches by the female the male showed no aggressive behaviour and moved away from the latter.

Agonistic behaviour towards the female, in the form of quick darting bites, preceded sometimes by what appeared to be a threatening posture (turning of the head and slight puffing of the opercles), in only a few instances caused the female to swim away from the male. Her usual response was to fan (identical to the fanning characteristic in parental care of the eggs), and edging closer to the male, sometimes against the body of the male, with the fanning undulating against his side. The male's usual response to such a behaviour was a movement away, but sometimes he remained motionless against the female.

Movement of the sexes away from each other was accompanied by a lowering of the dorsal and anal fins, and a

somewhat lightening of colouration of the male, although at times this latter was not obvious because of the pool illumination of the tank. The colouration of the female was always a light gray, in contrast to the dark brown colouration of the male. The anal and pectoral fins of the male were a bright orange and the caudal fin reddish. The dorsal fin was slightly tinged with red as well.

One characteristic behaviour shown by the male was that of digging depressions in the sand. In almost every observation period this behaviour was expressed. The body was turned slightly on its side, head held rigid against the end of the tank, and the posterior portion of the body vibrated very rapidly, sending out a spray of sand behind the fish. The process was repeated two or three times in succession, with the end result a depression was formed in the sand large enough to accompany one fish in a coiled position. The male did not occupy these depressions for long periods of time, nor did he show much aggression towards the female if she approached such holes. Approaches by the female, when the hole was being occupied by the male sometimes elicited what appeared to be a threat response (raising of the fins and gaping) but in other instances showed a complete lack of response.

On March 30, 1965, an egg mass was found beneath

the shell, with the female coiled and fanning. She had released her eggs sometime during the night or early morning. The last observation period was on the evening of March 29, 1965, at which time the fish appeared rather inactive.

Parental Care

In contrast to many other blennioid fishes, it is the female which stays with the eggs and provides parental care. With each egg mass located, Schultz and DeLacy (1932) found a female to be associated with it. In one case they found a male nearby, but it escaped capture. Results borne out by this study were similar; all located egg masses were being guarded by a female; no males were located near the site of the eggs and female.

Breder (1939) summarized data known for a number of species and reported the males of the following species to guard the eggs; Blennius gattorugine, B. montagui, B. pholis, B. ocellaris, B. sphynx and Clinus argentatus. Both parents may guard the nest of Pholis gunnellus.

In the previously named species, the eggs are adhesive. No fanning of the eggs has been described (Breder, 1939).

Observations in the Field

Lifting of a rock covering a nesting site did not appear to disturb the fish from its guarding position. The female was found to coil about the egg mass in a U-shape, somewhat more tightly under these conditions than when covered by water. No movements were made by the female until the egg mass was lifted from its resting position. This is a form of behaviour quite distinct from the usual fleeing observed when such disturbances occur at other times of the year.

Observations in the Laboratory

A female with her egg mass was placed into an aquarium on January 16, 1965 (hatching of eggs previously described) and her subsequent behaviour observed. The tank was set up with a small shelter of stones arranged in such a way that observations could be made from the front of the tank. The eggs were placed under the shelter and then the female introduced. Initial observations were curtailed for a day to allow the female to become accustomed to her surroundings. The tank was kept in darkness between observations.

Two days after first introduction to the tank signs of parental care were observed. The egg mass was observed to be out from the shelter of stones, in one corner of the tank, having either floated out or been moved out by the female. The female was coiled about the eggs and fanning rhythmically with the posterior half of her body. A later observation the same day revealed both mass and fish to be under the shelter of stones, the female coiled and fanning. For the duration of remaining periods of observation up to hatching, the female remained in this position and was never observed out from the shelter.

The dorsal and anal fins are erected and the caudal fin expanded, during fanning activity. In effect, this increases the surface area of the body in contact with the water.

The presence of light (a lamp was used during the observation periods) appeared to increase the rate of fanning, and if left for more than two or three minutes, caused the female to become quite restless beneath the shelter.

Fanning of the eggs was maintained up until the time of complete hatching. As was previously described, the first hatched fish was observed on January 29, 1965, but the mass was not completely hatched until February 3,

1965. Over this extended period of hatching, the fanning behaviour was maintained. On February 3, 1965, the female was observed to be out from the shelter and was removed. At the time of removal, she showed much aggression towards the intrusion by the net used to capture her, darting and biting at the mouth of the net.

Similar observations were made of the second female, whose spawned eggs were located beneath an abalone shell placed in one corner of the aquarium. The coiled position with fanning was maintained for the duration of the incubation period. At the time of her removal (day of hatching of the eggs, March 11, 1965), the same aggression was shown to the intrusion by the net as that shown by the previous female.

One example of parental care being provided to an unfertilized egg mass was observed. The eggs were released on March 30, 1965. The male at the time of the egg laying was partitioned away from the female. The eggs were guarded with fanning for six days. By April 9, 1965, coiling about the eggs was seldom seen and the female began to eat the eggs. By April 14, 1965, all eggs had been devoured.

Behaviour Between Sexes Subsequent to Spawning

Observations were made of the behaviour of Pair #2 subsequent to the female's release of eggs. At the time of egg releasing the sexes were partitioned by a clear sheet of glass. The partitition was placed diagonally in the aquarium. The egg mass was located beneath the shell at one end of the tank. The male could see and get close to the female (within 2 to 3") but was kept from actual contact with the female by the glass partition.

The partition was removed and the male allowed to move freely over the entire tank. At the end of 14 minutes of observation the male had not moved to the end of the tank where the female and eggs were located. The female during this time remained with the eggs, fanning, except for short movements around the shell with a return to the eggs each time. These latter movements indicated an awareness of the male's presence. Her head was turned in the direction of the male, appearing to watch the male but returning shortly to the eggs.

The male did not come close to the nesting site until 27 minutes of observation had been completed. At which time the female turned and darted out from under the shell, biting the male to the head, and then to the tail as

the male moved away. The male did not return to the region of the nesting site for the remainder of the observation period. The partition was replaced.

Further observations were made two days later (April 1, 1965), with the partition in place. Approaches by the male were met with the same expression of agonistic behaviour as before. The female darted to the partition, snapping against the glass.

The last observations were made on April 5, 1965; the same behaviour was displayed.

Discussion

The female Anoplarchus purpurescens guardsand tends its eggs. Such care is characterized by a coiling about the eggs in a U-shape, dorsal and anal fins erect, caudal expanded, and fanning. Schultz and DeLacy (1932) stated that the female on guard was party coiled around the eggs, but made no mention of any fanning behaviour.

The male plays no role in parental care, and is repulsed from the region of the nesting site by vigourous expressions of agonistic behaviour by the female. The latter consists of darting out from the nest, with eventual biting.

Care is provided continually, from just after spawning, to the time of complete hatching of the eggs.

Courtship display was observed, although the actual spawning act was unwitnessed. The term courtship is adopted here as it was defined by Morris (1956), as "the heterosexual communications systems leading up to the consummatory sexual act of fertilization." In some species this behaviour consists of one continuous complex, the courtship of the stickleback as an example. In other species, however, there are two quite distinct behaviour complexes--pair-formation and pre-copulatory display--which are separated in time. A. purpurescens shows a courtship behaviour of the latter type.

It is assumed that the courtship display observed was pre-copulatory display, as the fish were brought into the laboratory after they had paired up in the field. The initial pair-forming courtship was not observed and therefore cannot be distinguished from the subsequent pre-copulatory display.

The behaviour observed appeared to be rather limited. Baerends and Baerends-von-Roon (1950) showed in their study of cichlid fishes, that in species where both partners take part in parental duties, there is a greater distinction between pair-formation and pre-copulatory

ceremonies, than in those species in which only one sex performs parental duties. Anoplarchus may show similar courtship, and because of not observing the initial pair-formation display, the remaining pre-copulatory display appeared that much more limited.

Courtship display observed showed the male to be very aggressive to approaches by the female. This type of courtship in which the animal tends to attack its mate, is commonly shown by fishes, the stickleback's courtship being the most widely used example. Pugnacity is however, a feature well known for gobies and most territorial fishes (Tavolga, 1954). Morris (1954), observed this type of courtship in a cottid, Cottus gobio. The male of this species is extremely aggressive to the female, with courtship often beginning by the male swallowing the female's head in one huge bite. The female if ripe with eggs, responds sexually to the assault of the male and enters the nest, or allows herself to be carried in by him.

The female Anoplarchus showed a somewhat similar response to the aggressive actions of the male. There was no tendency on her part to flee the male when attacked, but rather, she would move closer to him, characteristically with a fanning movement of her body. The moving in close to the male appeared to be a direct response to the male's

aggressive attack. Guitel (1893) observed a somewhat similar behaviour for the female Clinus argentatus, who attracts males by means of body quivers.

The male Anoplarchus did not show any further aggressive behaviour once the female had positioned very close, remaining rather motionless or usually moving slowly away. There appeared to be a definite lack of sexual response to the female.

Morris (1954) pointed out that even in the very aggressive courtship of C. gobio, the male does not only attack the female, but also threatens her, thus revealing that his fleeing drive is also activated, if only slightly (threat being the result of a conflict between attacking and fleeing tendencies). The male Anoplarchus also showed what appeared to be a threat posture before actual aggressive attack; turning towards the female, gaping, erecting the fins and sometimes expanding the opercles. The latter behaviour has been shown for blennioid fishes; Blennius sphynx (Guitel, 1893), B. ocellaris (Pieron, 1914) and Paraclinus marmoratus (Breder, 1939, 1941).

Both Tinbergen (1952) and Morris (1956) have suggested reasons why there is so much aggression shown in courtship. Tinbergen feels that because the males have to fight one another, the females even when dimorphic, cannot

help stimulating the male's aggression slightly. Morris modified this view somewhat, by stating that territorial males cannot help treating intruding females as objects to be attacked as well as courted, because such males respond aggressively primarily to intrusion onto their territories and only secondarily to the nature of the intruding object. He suggests therefore, that the basis of pair-bond is removal of the attacking and fleeing tendencies, which permit the now unsuppressed sexual tendency to keep male and female together. Thus, it is possible to perform initial (pair-forming) courtship displays and then, having formed a pair-bond, wait for some time before attempting to achieve fertilization.

The successful spawning which took place by Pair #1, indicates that aggressive tendencies were overcome by sexual tendencies, allowing fertilized spawning to take place. With Pair #2, however, a successful spawning did not occur and the male appeared to remain aggressive towards the female for the duration of observation periods performed, resulting in subsequent egg release by the female.

Subsequent to spawning, during parental care duties, a distinct change in behaviour is shown by the female towards the male. She is now very aggressive to the male's approaches to the nesting site, biting and chasing him away. A few such attacks appeared sufficient in keeping

the male away from the nesting site.

AGE AND GROWTH

Introduction

The Length-Frequency Method

Most fishes have a more or less sharply defined breeding season, i.e., the young are born during a definite season of the year. If a large collection of a species is made over a short period of time (on one day, for example), the individuals of the sample should group themselves around certain modal sizes. Thus several peaks appear in the length-frequency curve of a multiple age population of fish, each peak (mode) theoretically representing an age group or year class. The distinctness of each of these modes would depend on the extent of overlap of length-frequency distributions of consecutive age groups. The overlap would of course depend on length of the breeding season, on rapidity and uniformity of growth within the species, and on length of the period of sampling.

It is sometimes possible to follow the growth of fish during one or several years by using length-frequency distributions. Length distributions are plotted from monthly samples and curves arranged one above the other on a diagram. With growth of the fish, its length distribution

curve for each age group is displaced to the right.

Validity of the length-frequency method for approximate age determination has ample substantiation, and has been applied widely in age and growth studies. However, three basic prerequisites are necessary for good results, and the following characteristics of the sample should be closely met:

(1) composed of a large number of individuals;
(2) collected in a restricted period of time (in a single day, preferably);
(3) good representation of all the size- and age-groups in the population.

These latter optimum conditions of the method were present in two respects, in the analysis to follow. Although sample sizes were not great, each collection was made on a restricted period of time, usually on one day (some were collected on two days, but were not separated in time by more than one week), and each collection revealed a good range in lengths.

Thirteen samples were utilized, providing 285 specimens. The first sample was collected in June, 1963 and the last in October, 1964. Length-frequency curves were plotted for each sample, and for the total collection and the sexes. Modal analysis was performed on the seasonal series of 13

samples. The various lengths exhibited were grouped into standard length groupings of five millimetres each.

Otoliths

A study of otoliths was performed to substantiate the length-frequency method of age and growth determination. A total of 70 otoliths were examined, utilizing the samples from June, 1963 to June, 1964.

The otoliths of Anoplarchus are very small (0.8 to 2.2 mm), and fairly transparent. No processing of the otolith was required, except for a drop of 100% glycerin, used as a clarifying agent. Opaque white and completely clear otoliths were discarded.

The otoliths were studied with reflected light, against a black background, which produces an alternation of wide white zones and narrow dark ones. The annual ring was taken as the border between the internal narrow zone and the external broad one. A small ring which was frequently found around the central core of the otolith, was disregarded and not counted as the first annual ring.

The otolith could only be read with any certainty in approximately one-half of the 70 otoliths examined. Thirty-four age determinations were made from the otoliths.

Results

Length-Frequency Analysis

The length-frequency distribution of the entire collection of 285 fish is shown in Figure 9, along with those of the males and females. The plot of the total collection indicates a possibility of four modes, which is further substantiated by the results of the modal analysis of each of 13 samples examined. Figure 10 shows the length-frequency distributions of each of 13 samples, and the modal analysis is presented in Table XVIII. Such analysis revealed a total of four modes, which could possibly represent age groups 0, I, II and III. The assumption that the first size group represents young of the year is not without foundation. As is generally known, most fishes grow more rapidly (in length) in early life than later. This rapid early growth would tend to make young size groups more clearly distinguishable in a frequency distribution than the older ones. Furthermore, the spawning season of Anoplarchus is in January and February. The first very small fish (25 to 30 mm) were located in June (1964), but were still being located in September and October, at a size of 30 to 50 mm. Their size precludes the possibility of their having been spawned in the previous year.

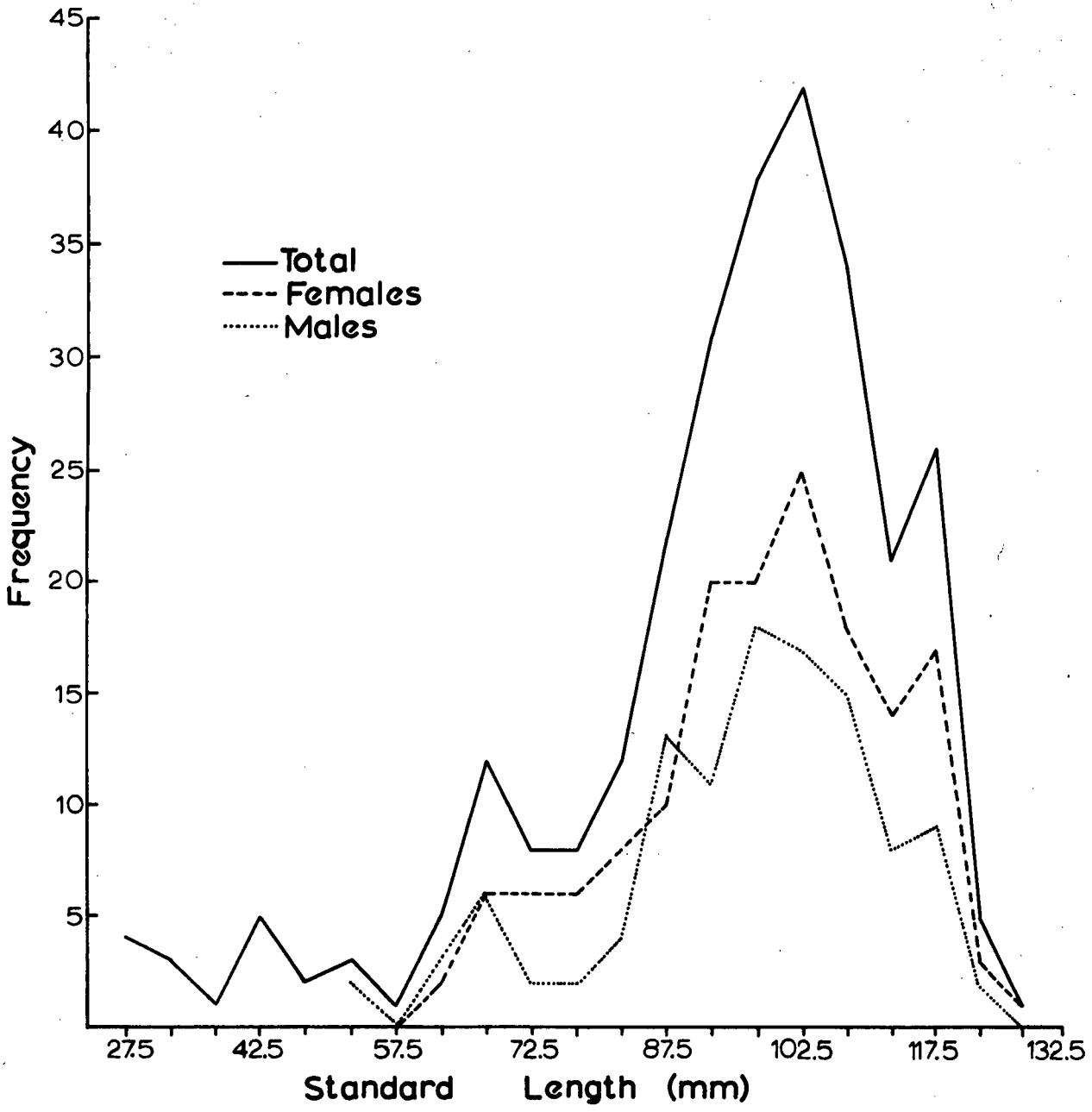


Figure 9. Length-frequency distributions; total of 285 specimens, 112 males, 157 females, 16 unsexed.

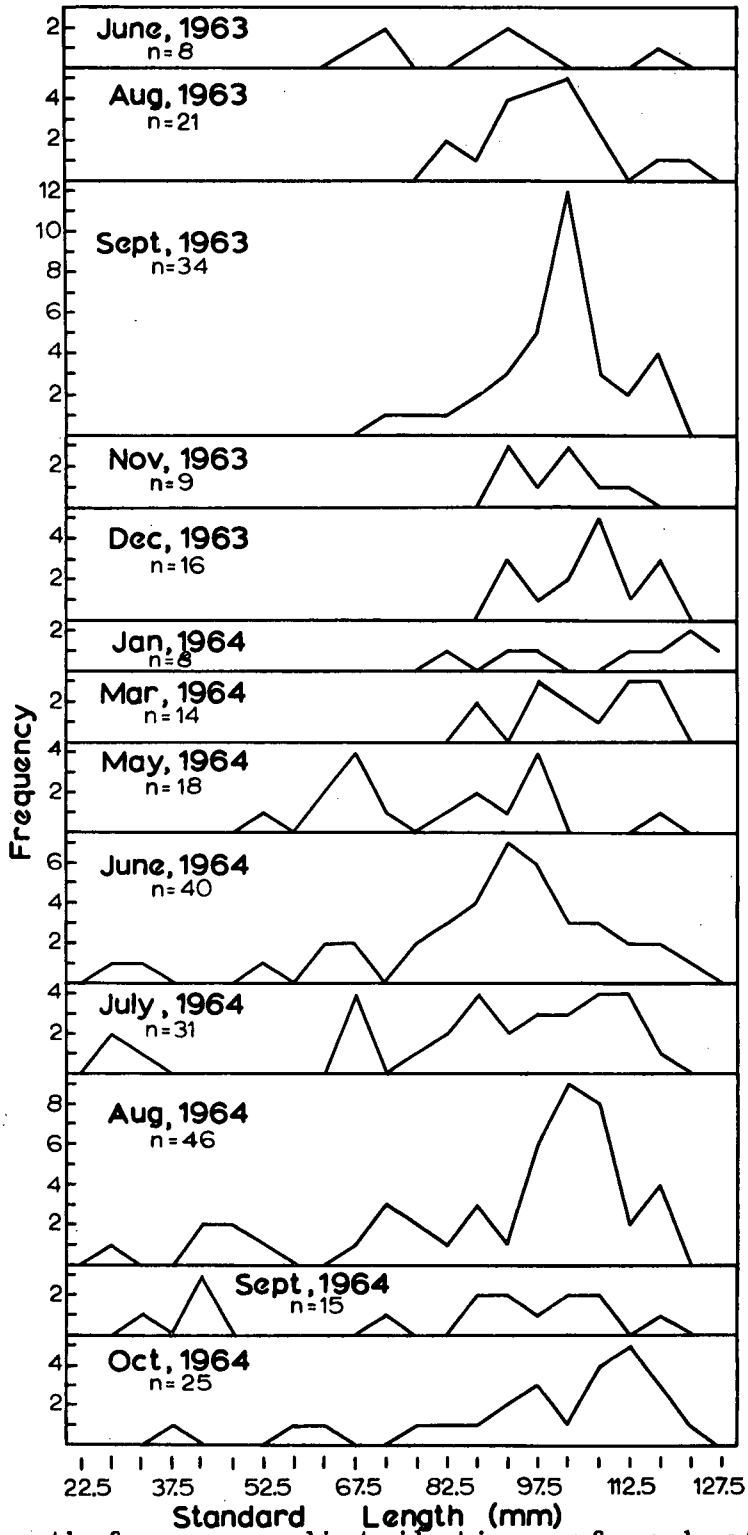


Figure 10. Length-frequency distributions of each of the 13 individual samples; total of 285 specimens.

Table XVIII. Modal analysis of each of 13 samples; increases and decreases in modal size between months and between the two years of sampling.

Date of Sample	Age Groups 0	I	II	III
Jun., 1963		72.5	92.5	117.5
Aug., 1963		82.5	102.5	120.0
Sep., 1963			102.5	117.5
Nov., 1963		92.5	102.5	
Dec., 1963		92.5	107.5	117.5
Jan., 1964		82.5	95.0	122.5
Mar., 1964		87.5	97.5	115.0
May, 1964		67.5	97.5	117.5
Jun., 1964	30.0	65.0	92.5	
Jul., 1964	27.5	67.5		
Aug., 1964	45.0	72.5	102.5	117.5
Sep., 1964	42.5	90.0	105.0	117.5
Oct., 1964	60.0	97.5	112.5	

Age group 0 is lacking from all samples collected in 1963, and does not show up until the June, 1964 sample. The apparent lack of young of the year in the samples of 1963 is probably attributable to selectivity in sampling. These samples were all collected in the uppermost mid-intertidal and mid-intertidal in a rather restricted area in comparison to the total study area (between pillars #8-14, beneath the bridge). Once sampling was furthered to other areas, starting with the May, 1964 collection, small fish of 50, 60 and 70 mm were obtained. These fish were of a size too large to be considered 1964 young of the year (as evidenced by later 1964 samples) and must have been young of the 1963 breeding season, now age group I fish. The smallest fish obtained in 1963 was a fish of 68.5 mm, in June; an age group I fish, hatched in 1962.

Otolith Analysis

Ages were determined from 34 otoliths, from a range in standard length of 51.5 to 123.5 mm, and over a time period of August, 1963 to June, 1964. The results are presented in Tables XIX and XX.

Five age groups were found to be present in this size range; I, II, III, IV and V, with the number of annular rings varying from one to five. Thus, ages from 1+ to 5+ years, representing year classes from 1959 to 1963, were

present.

The assumption made in the length-frequency analysis, that fish of 50, 60 and 70 mm, taken in the May, 1964 sample, do not represent young of the year, is further substantiated by the otolith readings. Fish from 50 to 80 mm were found to possess one annular ring and therefore must have been hatched in the previous year (i.e., 1963 year class). Fish from 80 to 90 mm, may have one or two annular rings, thus, may be 1+ or 2+ years of age. From 90 to 100 mm, fish are usually 2+ years of age, but may be 3+. Fish from 100 to 120 mm, are predominantly 3+ years of age, but may be 4+. Sizes of 120 mm and greater, may be 4+ or 5+ years of age.

Correlation of the Two Methods of Age Determination

Length-frequency analysis indicated the possibility of four age groups, from young of the year, age group 0, to age group III. It is apparent however, as evidenced by by the otolith readings, that the single modes are not representing fish of a single age. The latter is probably attributable to the small sample sizes, and is not corrected by the plot of the total collection (Figure 9) because of wide separation in time of the collection of each of the 13 individual samples. There is clear-cut distinction of young

Table XIX. Results of age determinations from 34 otoliths; 19 males, and 15 females.

Date of Sample	Males		Females	
	Length	No. Rings	Length	No. Rings
Aug., 1963	85.0	1	84.0	1
	101.0	3	92.1	2
	104.5	3	106.0	3
	108.0	3	115.0	3
Sep., 1963	94.8	2	98.8	2
	109.9	3	101.5	3
			114.0	3
			118.2	3
Dec., 1963	118.0	4		
Jan., 1964	83.0	2	92.0	2
	98.3	3	114.0	3
	123.5	4	120.0	5
Mar., 1964	86.0	2		
	86.2	2		
May, 1964	51.5	1	66.2	1
	53.9	1	67.2	1
	56.9	1		
	61.1	1		
	62.0	1		
	119.2	3		
Jun., 1964	84.0	1	61.2	1
			75.2	1

Table XX. Age composition of sexes (19 males, 15 females) by standard lengths, determined from 34 otoliths.

Standard Length	1		2		3		4		5	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
50- 60	3									
60- 70	2	3								
70- 80		1								
80- 90	2	1	3							
90-100			1	3	1					
100-110					4	2				
110-120					1	4	1			
120-130							1			1
Sums	7	5	4	3	6	6	2	0	0	1
Mean Length	64.91	70.76	87.50	94.30	106.82	111.45	120.75			120.00

of the year (age group 0) but with increasing fish size, the modes tend to overlap more and more, and thus do not represent single ages.

The otolith analysis covered a range in size which the length-frequency method indicated to represent age group I to III. Otolith readings however, showed five age groups, from I to V, to be present over this range in size, representing ages from 1+ to 5+. Thus, on the basis of otolith analysis, when the young of the year are included, the population of Anoplarchus studied is composed of individuals from less than one year of age, to greater than five years of age, representing year classes 1959 to 1963.

If only the length-frequency method of analysis had been employed, it would have been impossible to show the age differences between individuals within small size ranges. Many under- and over-estimates would have been made. However, the method does have value in approximating the age groups present and in this respect indicated fish of age 1 to age 4 to be present. But to separate individuals of different ages from a single mode, a method such as otolith analysis would have to be employed.

Growth Curve

Table XX shows mean lengths of the sexes, for each of the determined ages. These mean lengths were used to plot growth curves for the sexes, as presented in Figure 11. The point for young of the year (age < 1) is based on 15 specimens, collected between June, 1964 and October, 1964, of a range in length from 25.5 to 47.3 (mean 36.5) mm.

Rate of growth of the females from <1 to 1+ years of age is constant, whereas that of the males decreases. Thus, at 1+ years of age, the females tend to be slightly larger than the males. From 1+ to 4+ years of age, both curves show a similar decrease in rate of growth, with females remaining at a larger size than males at each age. Females of 4+ years of age were lacking from the sample of otoliths studied, thus the pronounced decrease in growth rate indicated from 3+ to 5+ years of age is probably over-emphasized as it is shown.

Although the curves are only based on 34 otolith readings, the complete range in standard length exhibited was examined and age differences between small ranges in size were analyzed.

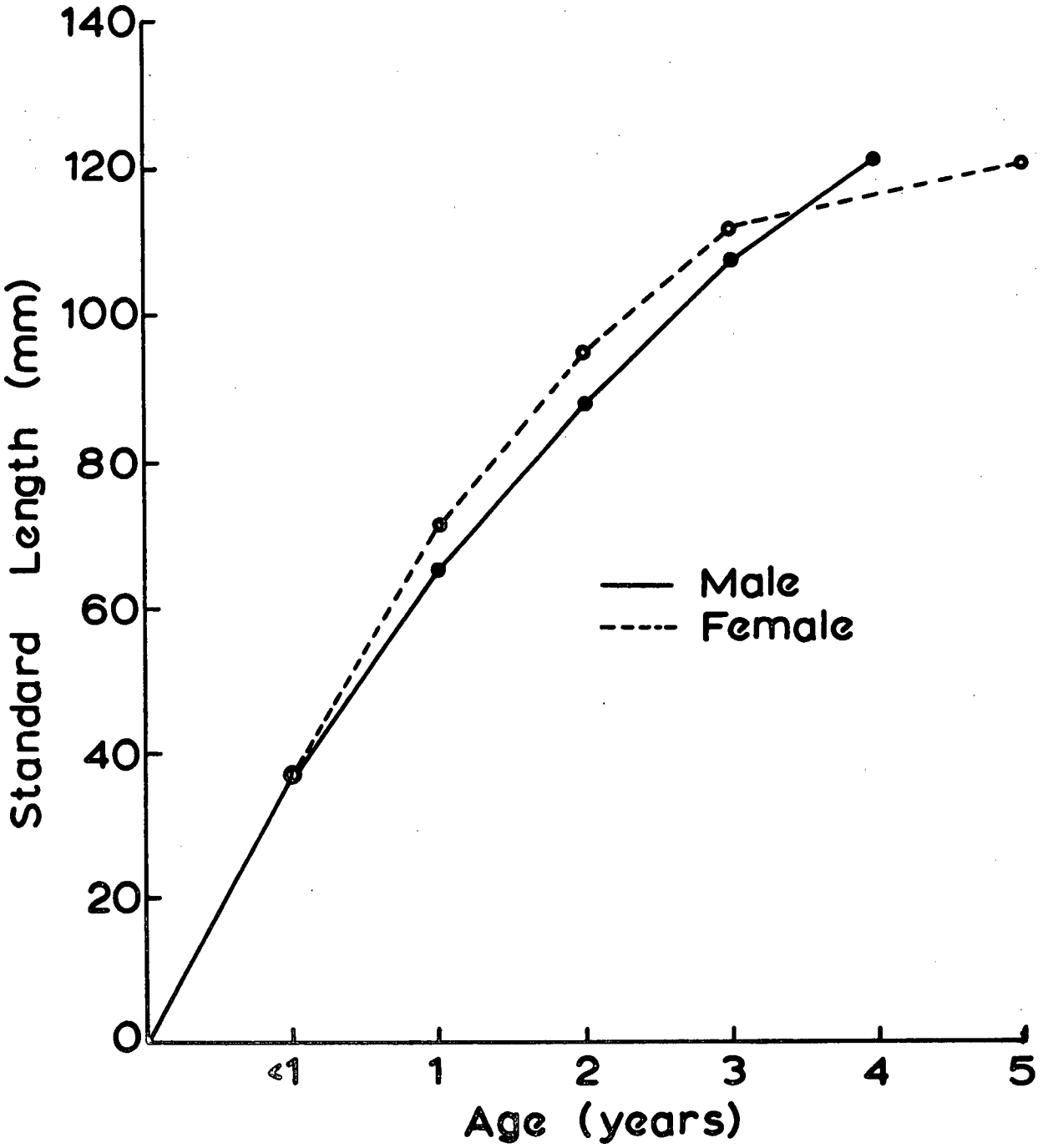


Figure 11. Growth curves of male and female Anoplarchus, based on 34 otoliths; 19 males, 15 females. Point of age < 1 based on 15 measurements.

Age at Sexual Maturity

The sexes show their first signs of maturity at a length of 80 to 90 mm. At this time, the testes are enlarging and the ovaries becoming granular. Spawning takes place for the first time at an age of 2+ or 3+ years.

Sex Ratio

Of 269 fish identified to sex, males accounted for 112 individuals (41.64%) and females, 157 individuals (58.36%). A sex ratio in favour of females of 1.4 : 1. This numerical superiority of females is constant over almost the entire range in standard length. Progressive changes in sex ratio are detailed in Table XXI, along with the percentage breakdown by sex of the various length groupings.

Length-Weight Relationship and Condition

Method

Preserved specimens from the 1963 samples of August, September, and December and the 1964 samples of January, May and July, were used. Weighing was performed

Table XXI. Percentage breakdown by sex of the various lengths exhibited, and progressive changes in sex ratio with increasing size.

Standard Length (mm)	Males			Females		
	No.	% of Total	% Sex	No.	% of Total	% Sex
50.0- 55.0	2	1.79	100.0	0		
55.0- 60.0	0			0		
60.0- 65.0	3	2.68	60.0	2	1.27	40.0
65.0- 70.0	6	5.36	50.0	6	3.82	50.0
70.0- 75.0	2	1.79	25.0	6	3.82	75.0
75.0- 80.0	2	1.79	25.0	6	3.82	75.0
80.0- 85.0	4	3.57	33.3	8	5.10	66.7
85.0- 90.0	13	11.61	56.5	10	6.37	43.5
90.0- 95.0	11	9.82	35.5	20	12.74	64.5
95.0-100.0	18	16.07	47.4	20	12.74	52.6
100.0-105.0	17	15.18	40.5	25	15.92	59.5
105.0-110.0	15	13.39	45.5	18	11.46	54.5
110.0-115.0	8	7.14	36.4	14	8.92	63.6
115.0-120.0	9	8.04	34.6	17	10.83	65.4
120.0-125.0	2	1.79	40.0	3	1.91	60.0
125.0-130.0	0			1	0.64	100.0
	112	100.00		157	100.00	

in August, 1964.

A total of 92 fish were examined (46 males and 46 females). Before weighing, all contents of the body cavities were removed. Each fish was placed on paper towelling, allowed to dry of excess moisture, and then before each was weighed, wrapped and squeezed lightly. Weighing was done on a Mettler precision balance, to the nearest 0.01 gram.

Factors for Conversion Between Standard and Total Length

The method presented by Beckman (1945) was employed. In the original compilation of standard and total lengths, each millimetre of total length was made a column heading and each standard length was recorded in the appropriate column. Average standard lengths and total lengths were computed for 5-millimetre intervals of total length. The ratio of standard to total length was determined for each of these intervals by dividing the average standard length by the average total length. For example, two fish in the 85 to 90 mm group of total length, averaged 86.6 mm in total length and 79.5 mm in standard length. The value 79.5 / 86.6 = 0.915 is the ratio for that group. A reverse of the latter, 86.6 / 79.5 = 1.089 gives the ratio for conversion of standard length to total length for that group.

The obtained conversion factors for total length to standard length ranged from 0.912 to 0.918, with no trend in increasing or decreasing with increasing length. The average ratio of 0.9145 was computed and represents the factor for conversion of total length to standard length.

The obtained conversion factors for standard length to total length ranged from 1.088 to 1.094, the average ratio of 1.0907 represents the factor for conversion of standard length to total length.

Length-Weight Relationship

The equation used in compilation of the length-weight relationship was that of the general parabola, $W = c\ L^n$, where W = weight in grams, L = total length in millimetres, and c and n are constants. This latter equation, according to Hile (1936), generally gives a better result in the expression of the length-weight relationship than does the cubic parabola, $W = c\ L^3$, where W = weight in grams, L = total length in millimetres, and c is a constant.

The equation, $W = c\ L^n$, expressed in logarithmic form becomes a straight line: $\log W = \log c + n \log L$. The values of log c and n were determined from the following equations:

$$\log c = \frac{\Sigma \log W \cdot \Sigma(\log L)^2 - \Sigma \log L \cdot \Sigma(\log L \cdot \log W)}{N \cdot \Sigma(\log L)^2 - (\Sigma \log L)^2}$$

and

$$n = \frac{\Sigma \log W - (N \cdot \log c)}{\Sigma \log L}$$

The method employed in compiling the data was that presented by Beckman (1945), and is illustrated in Table XXII. This Table is an excerpt from the original tabulation.

The obtained values for log c and n are as follows:

$$\log c = -5.31565 \text{ and } n = 2.98585$$

By substituting these values in the logarithmic form of the equation, $W = c\ L^n$, the calculated weights were determined. Table XXIII contains the length-weight data, including standard and total lengths in millimetres, emprical weight in grams and the calculated weights in grams. The length-weight relationship is presented graphically in Figure 12.

Coefficient of Condition

The coefficient of condition, K, was determined by the use of the following formula, $K = 100{,}000\ W / L^3$, where

Table XXII. Excerpt from data to illustrate the method employed for compilation of information on length-weight relationship

Total Length	Standard Length	No. of Fish	Ave. Weight	log L	log W	log L X log W	(log L)	Calc. log W	Calc. Weight
73.2	67.1	10	1.62	1.82672	0.12710	0.23218	3.33691	0.13866	1.37
105.3	96.5	11	5.59	2.02243	0.74741	1.51158	4.09022	0.72302	5.29
126.5	116.0	6	9.57	2.10209	0.98091	2.06196	4.41878	0.96088	9.14

Table XXIII. The length-weight relationship and coefficients of condition.

No. of Fish	Standard Length (mm)	Total Length (mm)	Empirical Weight (Gms)	Calculated Weight (Gms)	K
3	61.5	67.1	1.34	1.37	0.564
10	67.1	73.2	1.62	1.78	0.536
4	72.7	79.3	2.06	2.26	0.529
3	77.3	84.3	2.68	2.72	0.576
3	81.8	89.2	3.28	3.22	0.598
6	86.9	94.8	4.09	3.86	0.619
10	92.2	100.6	5.28	4.61	0.671
11	96.5	105.3	5.59	5.29	0.622
11	102.6	111.9	7.00	6.17	0.644
13	107.5	117.3	7.95	7.29	0.638
6	112.3	122.5	8.67	8.30	0.611
6	116.0	126.5	9.57	9.14	0.524
3	121.5	132.5	10.18	10.50	0.566
1	128.0	139.6	9.04	12.26	0.431

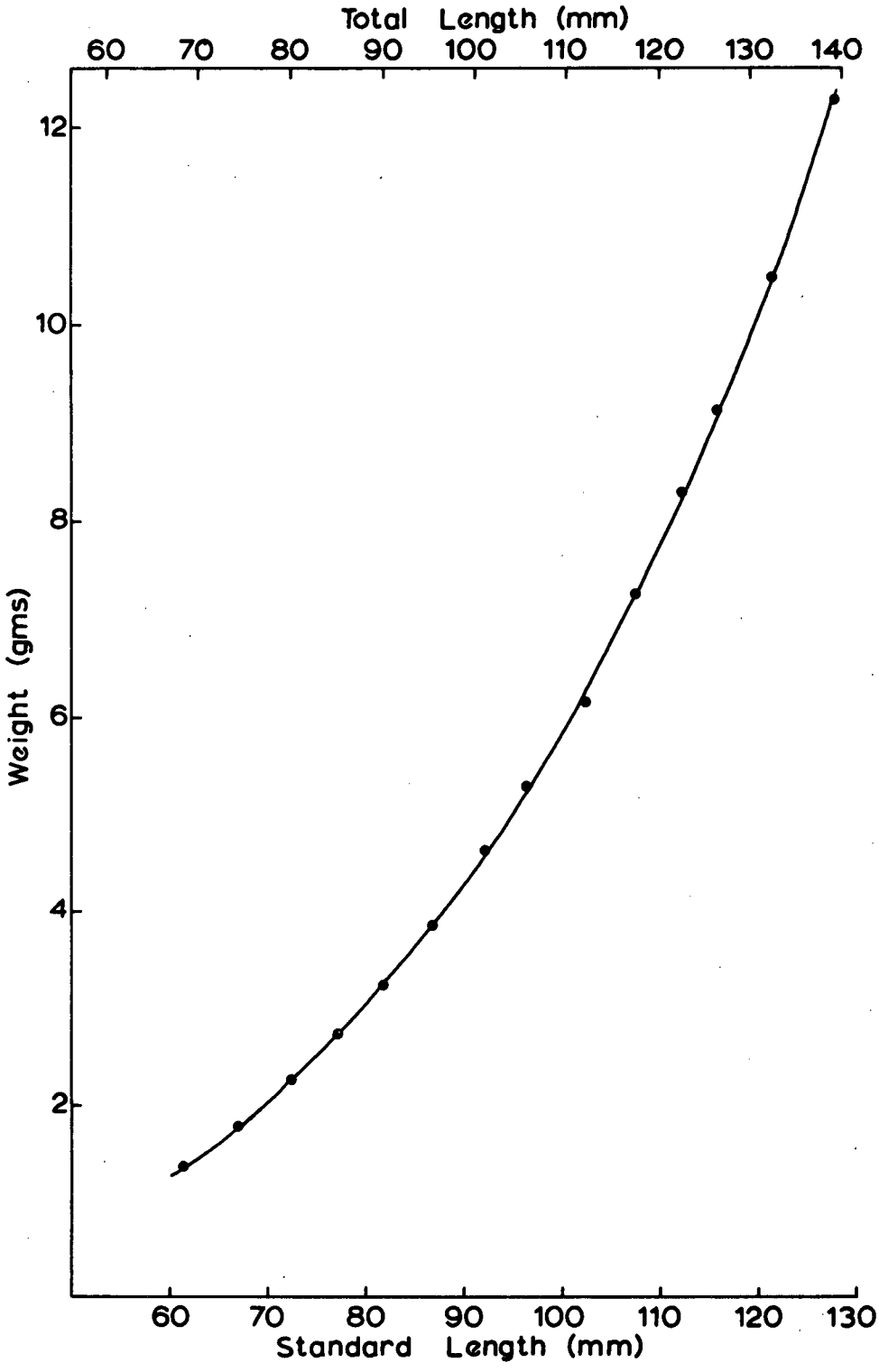


Figure 12. Length-weight relationship. The curve is the graph of the length-weight equation; dots represent the calculated data.

W = weight in grams and L = length (standard) in millimetres. Coefficients of condition calculated from the cube relationship describe relative heaviness independently of the general length-weight relationship, and are more satisfactory measures of condition than the quantity c, in the equation, $W = c\ L^n$, where the value of n is determined empirically (Hile, 1936).

The ranges and means of coefficients of condition obtained for each of six samples examined are shown in Table XXIV, where the $\bar{x}$ values for the sexes are presented separately. The average values for the grouped lengths are presented in Table XXIII, and graphically in Figure 14.

Comparisons between individuals of the same length, sex and time of collection, reveal a close similarity in values of the coefficient. Once comparisons are made between different lengths, opposite sex and collections separated in time, differences in the coefficients enlarge. Some examples of variation between individuals of the same length are shown in Table XXV.

Differences in the coefficient of condition between the sexes were not consistent, although the males were found to have a slightly higher mean value in all but one sample (Table XXIV). The mean values for both sexes show a seasonal trend in increasing in value from summer and fall months,

Table XXIV. Differences in coefficients of condition of 46 males and 46 females, of six samples examined.

Date of Sample	Males				Females			
	No.	Av. Length	Coefficient Range	Mean	No.	Av. Length	Coefficient Range	Mean
Aug., 1963	9	95.6	0.477-0.732	0.633	11	100.9	0.497-0.804	0.624
Sep., 1963	5	95.0	0.530-0.779	0.695	6	101.1	0.500-0.857	0.674
Dec., 1963	8	101.1	0.460-0.825	0.694	8	106.1	0.645-0.755	0.707
Jan., 1964	3	112.3	0.472-0.547	0.499	4	113.5	0.431-0.566	0.489
May, 1964	9	64.3	0.483-0.598	0.535	9	71.2	0.492-0.551	0.524
Jul., 1964	12	93.8	0.492-0.674	0.582	8	97.0	0.480-0.609	0.565

Table XXV. Variation in coefficients of condition among individuals of the same length; 10 comparisons between individuals of the same sex, 12 comparisons between individuals of opposite sex.

Date of Sample	Same Sex		Opposite Sex	
	Length	Coefficient Range	Length	Coefficient Range
Aug., 1963	108.9	0.565-0.645	92.2	0.732-0.804
			96.9	0.570-0.701
			108.9	0.565-0.588
Sep., 1963	94.9	0.740-0.779	95.0	0.702-0.740
			103.8	0.689-0.857
Dec., 1963	105.1	0.676-0.742	89.5	0.752-0.755
	109.1	0.715-0.718	91.7	0.460-0.729
Jan., 1964			114.5	0.479-0.493
May, 1964	61.3	0.562-0.563	66.3	0.493-0.522
	61.8	0.562-0.567		
	67.1	0.538-0.551		
Jul., 1964	86.6	0.576-0.607	68.0	0.480-0.595
	105.8	0.569-0.605	103.7	0.551-0.674
	109.5	0.598-0.609	112.0	0.548-0.579

reaching a peak in December, decreasing in January (the first month of the spawning period), and then rising again in the spring and summer (Figure 13). The decrease shown in the January sample tends to substantiate the previous conclusions made concerning feeding habits (discussion of food habits) of the species with the approach and during the breeding season.

Discussion

The length-frequency method of age analysis was applied and its validity for the samples studied qualified by otolith analysis. On the whole, length is a poor index of age. The amount of overlap between consecutive age groups is too great and in most cases a fish of a given length might have any of several ages. The largest contributor to this latter situation was likely the small sample sizes.

Otolith analysis was used to supplement the length-frequency method. The number of age determinations made by this method was not great, a total of 70 otoliths were studied, with each otolith examined a number of times. Either a consistent assignment of age was made, or the otoliths were marked as unreadable. Thirty-four age determinations were made. If only the length-frequency method

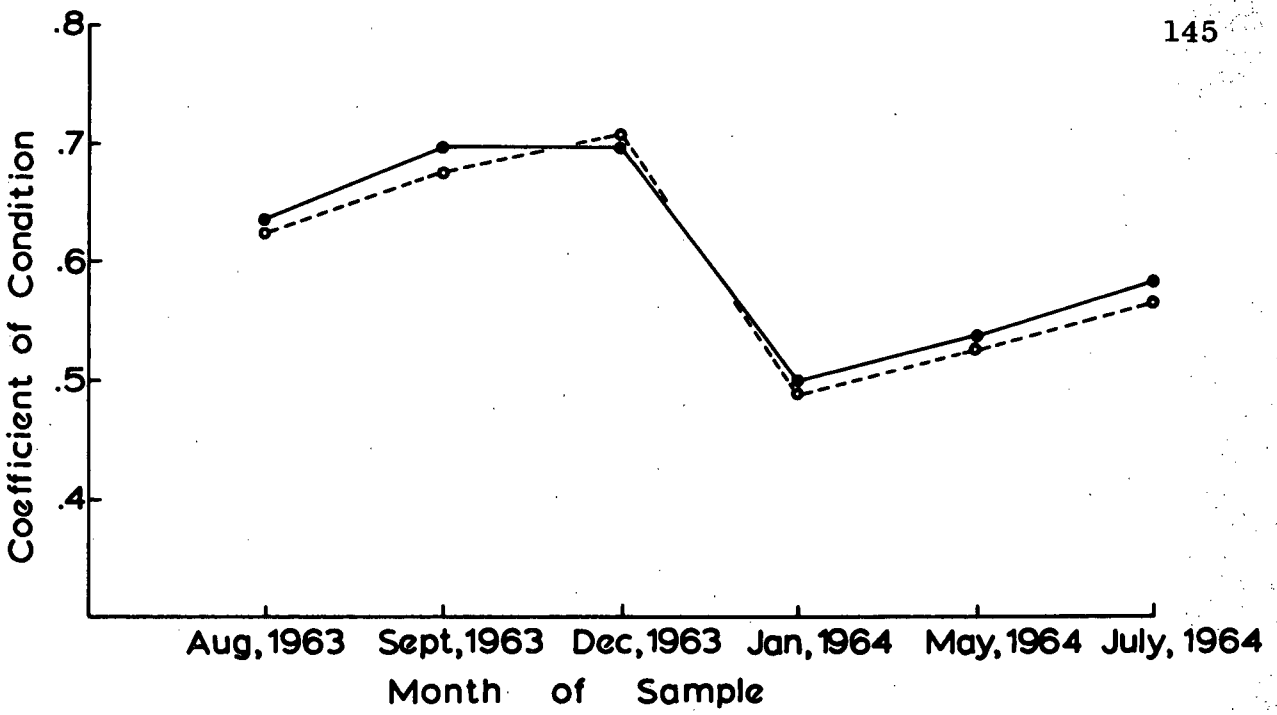


Figure 13. Variations in coefficient of condition of males (broken line) and females (solid line) in relation to the season.

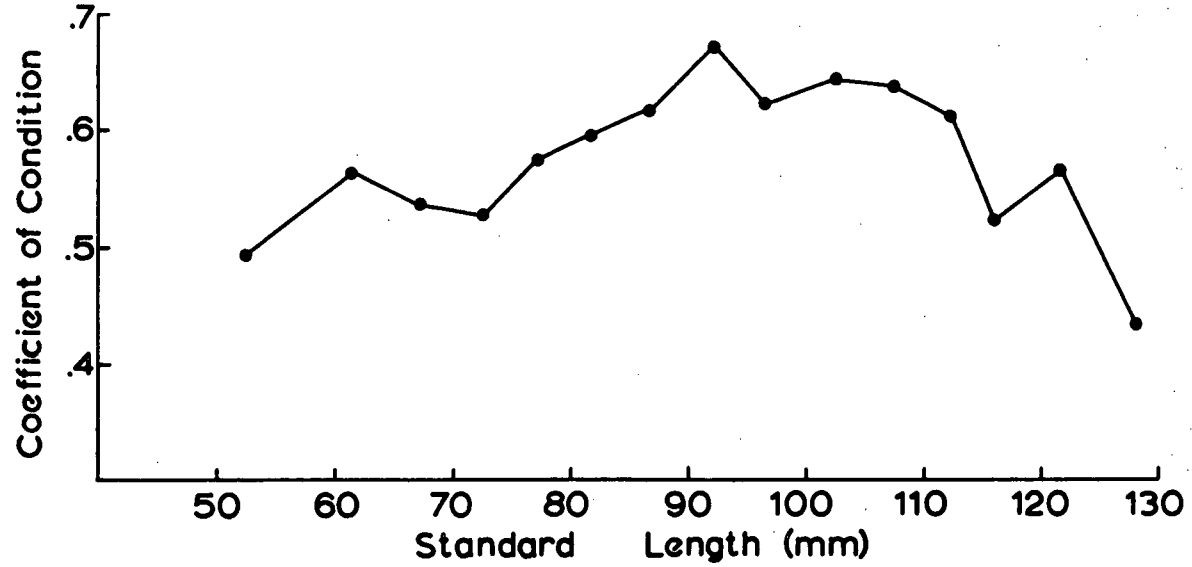


Figure 14. Coefficient of condition in relation to length of fish.

of analysis had been employed age differences between individuals within small size ranges would have been impossible to show.

The mean lengths of those individuals used for the otolith readings were used to plot growth curves for the sexes. The curves can be considered rather preliminary, due to their basis on only 34 fish, but the age determinations were made from a good range in length and did point out differences in age between individuals of approximately the same length. Sufficient variation in individual growth showed that the largest individual need not necessarily be the oldest. It is also true further, that the largest fish with respect to length is not always the heaviest (Tables XIX and XXIII).

The general equation, $W = c\ L^n$, was used to describe the length-weight relationship. The values of c and n in this equation were determined empirically. This equation, in contrast to the well-known cube law, $W = c\ L^3$, has been shown to be a much more satisfactory method of describing the length-weight relationship in fishes (Hile, 1936). As Hile pointed out, the use of the cube law in this latter capacity has met with indifferent success, due to the failure to describe accurately the relationships of length to weight in many forms of fishes. With scarcely an

exception, the weight at a given length is greater than the calculated weight from the law, so that if the specific gravity of the fishes remains constant they must increase somewhat more in other dimensions than in length.

The equation, $W = c\ L^3$, was however, used in the determinations of the coefficients of condition. Coefficients based on empirical exponents fail to reflect differences in form or relative heaviness, while those based on the cube relationship offer a direct measure of relative heaviness independent of the general length-weight relationships and comparable as measures of relative heaviness between fish of any length (Hile, 1936). The following reasoning is put forth by Hile. Inasmuch as relative heaviness is shown to be dependent on fatness (condition), changes with length in relative heaviness must be considered also to represent changes of condition. In view of this fact it does not appear valid to measure condition in terms of a quantity that tends to be constant for fish of all lengths regardless of actual changes that may occur in relative heaviness of form with change in length. Since the quanity c in the equation, $W = c\ L^n$, tends toward this constancy and fails to measure relative heaviness, it must fail also to measure the differences of fatness (condition) upon which differences in relative heaviness depend.

The coefficient of condition was used chiefly as a measure of the state of nourishment. The fluctuations obtained were due to some changes in composition of the body tissues, presumably an increase or decrease in the fat content, and not to the amount of food in the alimentary tract or to the growth of the sex organs, as the digestive tract and organs and the gonads were removed before weights were taken. Used in this way, the coefficient has value in supplementing the food habits analysis.

SUMMARY

(1) Systematics

Anoplarchus purpurescens is a perciforme teleost belonging to the suborder Blennioidei, family Stichaeidae. The genus Anoplarchus is placed within the subfamily Alectriinae, along with the genera Alectrias and Pseudalectrias.

A. purpurescens and its sibling species, A. insignis, are geographically sympatric, but in British Columbian coastal waters, the latter prefers deeper water than A. purpurescens. The range of A. purpurescens is wide, from Attu Island and the Pribilof Islands, Alaska, to central California.

In the area where collected and adjacent waters, A. purpurescens can be distinguished from all other blennioids by; absence of pelvic fins, presence of the dermal crest on the head, scales on the posterior half of the body only and the great width between the points of attachment of each gill membrane to the isthmus. It may be distinguished from A. insignis by its lower meristic counts and the greater width between the points of attachment of each gill membrane to the isthmus.

The species was first recorded in British

Columbian waters in 1861 from Vancouver Island and the mouth of the Fraser River by A. Günther, as Centronotus crista galli.

(2) Habitat

Anoplarchus is a bottom-dwelling form, inhabiting the intertidal zone, from upper mid-intertidal to low-intertidal. Its occurrence in the uppermost part of the mid-intertidal, places it higher up in the intertidal zone than any other "eel blenny" in the area. Anoplarchus is very closely associated with the substrate of rocks and algae, occupying available spaces beneath the rocks for day to day activities as shelter and feeding and special requirements as spawning.

Animal associates include a number of bottom-dwelling crustaceans and fishes.

(3) Movements

Marking experiments did not indicate a strong tendency to home but they did show movements of Anoplarchus to be rather restricted. Of the total number of fish recaptured, 58.0% showed a homing tendency. The straying was observed to be of two types; either to the transplant area or, to some other area. Straying of the latter type

was shown by 34.0% of those fish recaptured. Marked fish however, were rarely found more than 50 feet from where originally captured.

Anoplarchus displays both home-range and defended territoriality. Individuals share a home-range territory during non-breeding times of the year, but during the breeding season, individuals are highly segregated, spacially and sexually, into isolated breeding pairs. At this time defended territoriality is exhibited.

The small breeding territory appears to be maintained by aggression on the part of the male before spawning, and by the female once spawning is complete. The latter defence is maintained through the period of egg incubation, to the time of hatching.

(4) Food and Feeding

Anoplarchus appears to be a daylight feeder, utilizing as food those organisms present and available in the particular habitat being resided in at the time of feeding. Relative importances of the various food items reflected differences in availability of the organisms utilized as food in different tidal levels of the intertidal zone. In utilization of one food item, algae, there appeared to be a definite preference for green algae.

Anoplarchus can be considered fairly stenophagic in its food habits. Basic foods include; algae, polychaete worms (excluding nereid worms), nemertean worms, amphipods and flatworms. Mussels, littorine snails, isopods and nereid worms compose the remaining portion of the diet. The basic foods are utilized by Anoplarchus of all sizes. Food intake is curtailed in adult fish approaching and during the breeding season.

(5) Reproduction

Sexes are dimorphic; colouration and markings of the body at all times of the year, cockscomb when sexually mature and size.

Fecundity is high (2,001 to 3,183 eggs). The entire egg production of each female is concentrated into a single spawning act. Number of eggs increases with increasing female size. Average diameter of the eggs is 0.864 mm and 1.372 mm, for unfertilized and fertilized eggs, respectively.

The sexes form pair-bonds before actual spawning. Pre-copulatory display shows the male to play a very aggressive role, with threat display and actual biting. Spawning takes place in the months of January and February.

The female A. purpurescens guards and tends its eggs; characterized by coiling about the eggs and fanning. During parental care of eggs the male is repulsed from the nesting site. Care is provided continually to complete hatching of the eggs.

Hatching times of 13 and 16 days were obtained for temperatures of 10 to 12°C and 7 to 9°C, respectively.

The newly hatched larva is 7.4 to 7.6 mm in total length, fairly transparent and pigmented at several positions on the body with melanophores. An oval yolk sac with single oil droplet is present for five days. The larvae show marked positive photoaxis for three to five days, then are negatively phototactic.

(6) Age and Growth

On the basis of length-frequency and otolith analyses, the population of Anoplarchus at the time of the present study was composed of individuals from less than one year of age, to greater than five years of age; age group 0, to age group V, representing year classes 1959 to 1963.

Females show a slightly faster rate of growth than males and are larger than males at all ages.

Spawning for the first time occurs at an age of 2+ or 3+ years.

A sex ratio in favour of females of 1.4 : 1 was shown for 269 fish. The sex ratio remains in favour of females over almost the entire range in length exhibited.

The value of the exponent n, in the length-weight equation, $W = c\ L^n$, was found to be 2.98585; log c -5.31565.

Males show slightly higher mean values for the coefficient of condition, than the females. Both sexes show a synonymous seasonal trend in the values of the coefficient. The coefficient was at its lowest value for specimens collected during January, the first month of the spawning period.

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