鱼类及海洋动物
趋光生理研究論文选集

何大仁 主编

厦门大学出版社

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Selected Works on the Phototactic Physiology of Fish and Marine Animals

何大仁 主编
Edited by
He Da-ren
Department of Oceanography
Xiamen University, Xiamen, China

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前　言

何大仁

（厦门大学海洋系）

光诱捕鱼在我国有悠久历史，古代，我国渔民就早已采用松明诱集乌贼和鱿鱼，在内河用灯火诱集河蟹，并用火把配合鸬鹚捕鱼。本世纪三十年代，福建东山和广东南澳渔民就已经采用汽灯作为集鱼灯诱捕兰圆鲹，沙丁鱼了。随着底层鱼类资源面临枯竭情况下，五十年代以来，世界上许多国家转向开发资源丰富的中上层鱼类，而灯光捕鱼是当前捕捞中上层鱼类的一种主要生产形式，随着科学技术发展和灯光技术改进，使得灯光捕鱼成为技术先进的一种作业形式，在许多国家的海洋渔业中占有重要地位。中国沿海中上层鱼类资源丰富，种类很多，如鲐鱼、兰圆鲹、沙丁鱼、竹䇲鱼、圆腹鲱等已成为灯光围网的主要捕捞对象。1963－1965年，当时厦门大学生物系海洋生物教研室的同志及部分做毕业论文的大学生（由立书院教授和我负责）和厦门、东山的渔民及水产工作者共同试验用水下电灯捕鱼成功，同时进行了闽南渔场中上层鱼类资源，鱼类趋光行为的海上观察，海上水下灯照度测定，兰圆鲹等适宜光强光色的行为学室内水槽试验，兰圆鲹、沙丁鱼视网膜组织生理学研究等。由于文化大革命使这项工作停顿下来。六十年代后期到七十年代初，厦门、东山等地渔民生产中，机帆船灯光围网得到巨大发展，七十年代初期，上海渔业公司等单位开始发展机轮灯光围网，进一步开发我国沿海中上层鱼类资源，使中上层鱼类的捕获量大增，并在总渔获量中占很大比例。但是，要进一步提高灯光捕鱼水平，必须解决生产中提出的问题。例如，对兰圆鲹、鲐鱼来说，最适宜的颜色光源是什么？它们的适宜照度是什么？为什么月光夜的灯光诱集效果不好？为什么生殖季节趋光性差等问题，这些都牵涉到鱼类趋光生理的问题。为此，开始是1970年厦门大学海洋系海洋生物教研室的同志，分头深入闽、浙、粤沿海渔村，随灯捕渔船出海生产，总结群众灯光捕鱼经验。后来，1972、1973年我们和上海生理研究所，东海水产研究所的同事合

作，在福建厦门、东山、广东港口，山东青岛等地共同用行为学、电生理学及视色素生物化学等方法，对主要海洋中上层鱼类兰圆鲹、鲐鱼的趋光特性进行了综合研究，部分解决了上述理论和实际问题，并和厦门灯泡厂，厦门市渔捞公社等单位共同用钨铟灯等新光源进行海上试验，获得良好结果。发表了“在光梯度条件下兰圆鲹、鲐鱼的行为反应”“背景光对兰圆鲹、鲐鱼趋光反应的影响”“兰圆鲹、鲐鱼对等能光谱色的趋光反应”“兰圆鲹、鲐鱼视网膜电图的一般特性”“兰圆鲹、鲐鱼视网膜电图 b 波的光谱敏感性”“鲐鱼视顶盖诱发电位的一般特性和光谱敏感性”“兰圆鲹、鲐鱼视紫红的初步分析”等论文十余篇。其成果获得1978年中国全国科学大会奖。

后来，我们继续进行鱼类及海洋动物趋光生理（包括视觉电生理，趋光行为及视网膜组织学）理论和应用研究、研究对象包括：兰圆鲹、金色小沙丁鱼、孔沙丁鱼、勃氏银汉鱼、鲻鱼、鲈鱼、黄鳍鲷、鲤鱼、草鱼、尼罗罗非鱼、无针乌贼、杜氏枪乌贼、长毛对虾、中国对虾、三疣梭子蟹、锯缘青蟹、虎头蟹等。1984—1987年获项目名称为“闽南地区鱼类及其它海洋动物趋光生理研究”的中国科学院科学基金赞助。在本时期中发表了“不同照度下鲻鱼幼鱼摄食强度及其动力学”“几种幼鱼视觉运动反应研究”“尼罗罗非鱼视觉运动反应的特点”“影响尼罗罗非鱼视觉运动反应的因素”“锯缘青蟹复眼的单一感受系统”“锯缘青蟹视网膜电图特性的昼夜节律变化”“切断视神经对蟹视网膜电图昼夜节律的影响”“赤点石斑鱼视觉特性”“普通鲻鱼和棱鲻视觉特性的电生理研究”“无针乌贼视网膜电图的特性”“无针乌贼视网膜电图的光谱敏感性”“三疣梭子蟹的视网膜适应特性”“长毛对虾复眼的感受系统及其适应特性”“普通鲻鱼视网膜组织学研究”“黄鳍鲷和普通鲻鱼幼鱼视网膜运动反应初步研究”等论文二十多篇。

本选集选编了我组同志参加工作的自从1975年以来在各级刊物上公开发表的代表性论文36篇，其中包括行为生理学方面论文15篇，电生理学方面论文19篇，视网膜组织学方面论文2篇，供有关人员参考。文章顺序按发表时间先后排列。以下对我国在鱼类及其他海洋动物趋光生理研究作一综述。

一、行为生理学研究：何大仁、俞文钊等用光梯度方法研究了兰圆鲹、鲐鱼、孔沙丁鱼，勃氏银汉鱼、扁颌针鱼、天竺鲷、棱鲻、杜氏枪乌贼的趋光行

为；郑美丽、何大仁等对曼氏无针乌贼、罗会明等对鳗鲡幼鱼和三疣梭子蟹的趋光行为进行了研究。他们研究内容包括动物对光反应阈值，最适照度范围，对色光反应及背景光对趋光行为影响等。阐明动物上述特性，能为生产上选择适宜的人工光源，确定有效诱集范围和计算集鱼率等问题提供理论依据。

主要结果为：兰圆鲹、鲐鱼幼鱼和成鱼在10^{-1}－10^{3}勒克司水平光梯度下都表现积极趋光性，幼鱼趋光性比成鱼强，当水温为24.5－27℃时鲐鱼幼鱼适宜照度区在10^{-2}－14勒克司。个体和群体对光反应基本一致，且群体反应更稳定。并用扁颌针鱼、天竺鲷、棱鳀做对比试验，结果表明：扁颌针鱼总是分布在每组光梯度相对最强的照度区内，而在相同条件下，天竺鲷始终稳定分布在每组光梯度内相对最弱的照度区，而兰圆鲹幼鱼和成鱼，鲐鱼、棱鳀幼鱼的趋光性介于它们两者之间。鲐鱼和兰圆鲹都属于对光有正反应，但不是趋最强光的类型，两者比较，兰圆鲹趋光性比鲐鱼强，所以，这两种鱼都可作光诱对象。杜氏枪乌贼，曼氏无针乌贼的适宜光照区分别为10^{-1}—10^{1}勒克司和10^{-2}－10^{1}勒克司，都属于趋弱光类型。三疣梭子蟹最适照度区在10^{-3}—10^{-2}勒克司。随生长发育过程，鳗鲡幼鱼适宜照度区从10^{1}-10^{2}勒克司逐渐移至10^{-2}—10^{1}勒克司，说明其不同发育阶段，趋光特性是不同的。

某些鱼类和海洋动物能对色光产生选择性反应和有颜色视觉，这方面的研究对生产上光源颜色选择具重要意义。在暗适应条件下，兰圆鲹幼、成鱼对兰绿色光趋光率最高，对红光趋光率最低，由暗适应向明适应过渡后，对黄、绿光趋光率最高。鲐鱼在暗适应和明适应条件下都对紫光和红光有最大趋光率，但其光谱敏感峰却在兰绿光。作者提出适应的光色和敏感的光色是有差别的。杜氏枪乌贼对兰光具最大趋光率。

月光作为背景光，对光诱效果的影响是生产上的一个实际问题。实验证明，背景光都会降低上述动物的趋光性。而适当提高照明光强能抑制背景光的影响，趋光性强的动物受背景光影响小于趋光性弱的动物。但是，例外的是在10^{1}-10^{3}勒克司范围内，有背景光时杜氏枪乌贼的趋光率反而比无背景光时高，这种特殊现象与枪乌贼性成熟和月夜生殖有关。因此，和一般趋光性鱼类相反，在生殖季节月夜的捕枪乌贼，若适当增大光源强度，有可能提高产量。水温能影响兰圆鲹幼鱼的趋光性，在较低的适温范围，能提高其趋光性。

何大仁等还研究了在不同照度下鲻鱼幼鱼摄食的强度，以探讨视觉在鱼类摄食时的作用。结果表明，鲻鱼幼鱼对潘的摄食强度受光照强度影响很大，其摄食强度在10^2勒克司照度下达最大值，摄食率在10^2勒克司时最高，并在20分钟时达最大值。幼鲻摄食活动高峰只出现在一定光照条件下，与其在自然条件下摄食活动具明显昼夜节律性密切相关。证实视觉在其摄食活动中起重要作用，为鲻鱼养殖业上确定投饵时环境亮度和投饵量提供依据。

何大仁等从1984年开始又进行了鱼类视觉运动反应的研究，先后研究了鲻鱼、鲈鱼、黄鳍鲷、鲤鱼、草鱼等幼鱼的视觉运动反应特点。刘理东、何大仁等对尼罗罗非鱼的视觉运动反应及其影响因素进行了全面研究，包括环境照度，屏幕转速，水温，视野结构和体长等因素对尼罗罗非鱼视觉运动反应的影响，并描述了个体、群体及单眼鱼的反应特点。表明该种幼鱼在10^{-5}～10^4勒克司照度下具有典型的视觉运动反应，在一定范围内，鱼的视觉运动反应随环境照度和水温的升高而增强，随屏幕转速和体长的增加而减弱。鱼对黑白垂直条纹的反应最好，对倾斜条纹的反应较差，水平条纹则不能引起明显的反应。就垂直条纹而言，在一定范围内，反应随条纹宽度和数量的增加而增强。个体和群体的反应无明显差异。单眼鱼反应明显弱于正常鱼，并有显著的方向性。周仕杰、何大仁研究了中国对虾幼虾对运动物体的感觉能力及其与环境照度关系。他们还研究了色光条件下黄鳍鲷幼鱼的视觉运动反应。

二、十多年来，我国在鱼类及其他海洋动物视觉电生理方面做了很多工作。鱼类及其他海洋动物的趋光特性，是直接与其视觉功能相联系的，测定视觉系统周边与中枢各级神经元的电活动，是趋光生理研究中较理想的指标之一。我国的工作主要是用狙电极进行ERG特性研究。杨雄里等对兰圆鲹和鲐鱼ERG进行了全面研究，发现它们的ERG具典型的混合型视网膜特征，有比较明显的撤光反应，其b波对缺氧极为敏感。背景光可使视网膜的敏感性阈值明显提高，这同行为学的研究结果是一致的。郑微云等研究赤点石斑鱼时看到，其视网膜具视杆和视锥两种感光系统，但ERG却未发现混合视网膜典型特征，认为该种鱼视锥在某种程度上退化，适应于弱光视觉，无辨色能力。杨雄里等测定了兰圆鲹、鲐鱼ERG b波的光谱敏感性，表明两种鱼暗视光谱敏感曲线峰值分别在490和480毫微米，明视光谱敏感曲线峰值分别移至520和575毫微

米。还对鲐鱼视顶盖诱发电位进行研究，以诱发电位潜伏期为指标得出的光谱敏感曲线同ERG 暗视光谱敏感曲线基本一致，故认为光谱敏感性在视中枢没有发生变化。郑微云、柴敏娟、陈重、刘理东等人对无针乌贼、三疣梭子蟹、长毛对虾的ERG 特征分别进行了研究。表明这些无脊椎动物ERG 均为简单的角膜负波，有一正相的撤光反应，这与它们的视网膜结构和排列顺序是一致的。杨雄里等对锯缘青蟹不同适应条件下ERG 的光谱敏感特性的分析，提出其复眼仅具有单一感受系统，并揭示其ERG 敏感度的昼夜节律性。并提出蟹视网膜电图昼夜节律控制的模式图。柴敏娟等对几种甲壳动物（锯缘青蟹、虎头蟹、三疣梭子蟹、长毛对虾）ERG 昼夜节律性进行比较研究。近年来我国学者也开展了微电极研究，杨雄里等做过淡水鱼在体网膜水平细胞电位记录。

三、视色素生物化学和视网膜组织学研究。由于视色素是视网膜感光的物质基础，因此对其研究引起人们普遍重视。我国在视色素生化方面的工作还不多。

陈明等人对兰圆鲹、鲐鱼、青鱼、草鱼、鲢、鳙、罗非鱼等视杆视色素进行测定。发现青鱼、草鱼、鲢、鳙均为单纯网膜醛$_2$ 色素，光谱吸收峰值分别为530，528，525 和527 毫微米，鲐鱼为网膜醛$_1$ 色素，吸收峰在500 毫微米。兰圆鲹含有两种视紫红，吸收峰分别为488，510毫微米。罗非鱼含有网膜醛，和网膜醛$_2$ 的混合色素，吸收峰分别为500 和520 毫微米。

郑美丽、肖金华等研究了曼氏无针乌贼的视网膜组织学结构。徐永淦、何大仁等对普通鲀鱼、黄鳍鲷、赤点石斑鱼、兰圆鲹、金色小沙丁鱼的视网膜进行组织生理学研究。同时还进行了一些亚显微结构研究，讨论了五种海水鱼视网膜形态、机能与生态环境的关系。徐永淦、何大仁、章厚泉还进一步对黄鳍鲷、普通鲐鱼幼鱼，赤点石斑鱼，大弹涂鱼的视网膜运动反应进行了研究，并对视网膜运动反应机理进行了初步探讨。

以上介绍的是二十多年来我国鱼类及其他海洋动物趋光生理研究概况。在趋光生理及其相关领域，不少问题尚待研究。例如研究的鱼种不多；除兰圆鲹鲐鱼采用多种方法研究外，其他种类还只是侧重某个方面研究，对视色素生物化学研究很少，影响鱼类趋光的因素缺乏系统研究，鱼类趋光机制，亮度与色觉关系，感觉系统与运动系统的联系等理论问题均必要进行深入的探讨。通过

趋光行为研究，开创了我国鱼类行为学的研究，但是，鱼类行为学研究在我国才刚开始，在实验方法和研究手段上，过去室内工作多，海上实际观察少，实验技术也待改进，如行为学研究，近年，虽已采用微电脑、闭路电视系统、红外夜视仪等装置，但还需采用自动记录、分析装置代替肉眼观察，电生理中微电极、超微电极的应用。因此，在鱼类及海洋动物趋光生理、视觉生理及行为学研究我国过去十几年来已取得成绩，某些领域的研究接近世界水平，但是有些学科我国至今仍是空白或与世界水平有差距。趋光生理及鱼类行为学研究具重要理论价值与实践意义。为了赶上世界科学技术的发展，今后必须继续深入进行趋光生理及相关学科研究。

The Studies on the Physiology of Phototaxis of Fish and Marine Animals in China

Daren He
Department of Oceanography, Xiamen University,
Xiamen, China

Lightfishing has a long history in China. It can be traced back to the ancient time when our fishermen used pine-torches to lure cuttle fish and squid in the sea and used lamps to lure crabs and torches as an aid to catching cormorants. As early as in the 1930s, the fishermen of Dongshan, Fujian and Nanao, Guangdong already used gaslamps as gathering lamps to lure and catch round scads and sardines. With the deptetion of demersal fish resources, many countries in the world have began to exptoit the rich resources of petagic fish since the 1950s. At present, lightfishing is one of the important means in catching petagic fish. With the development of science and technology and the improvement of lighting technology, lightfishing has become and advanced means of production, which plays an important role in marine fishery in many countries. China's coastal waters abound with both varieties and quantities of petagic fish, of which chub mackerels, round scads, horse mackerels, round herrings, sardines etc. have already become the major objects for purse seiner fishing with light. In the early 1960s, we carried out successful experiments in underwater lamp fishing together with the fishmen of Xiamen, Dongshan and other areas. From the late 1960s to early 1970s, the fishermen of Xiamen, Dongshan etc. made tremendous

strides in motorized junk seine with light in their production. In the early 1970s, Shanghai Fishery Company and other units began to develop purse seiner fishing with light, furthering the exploitation to the marine pelagic fish resourse of our country, and rasing the proportion of the pelagic fish yield in the total. But to raise the light fishing level further, we must solve the problems that arise in production. For examples: What is the optimum color light sourse for round scad and chub mackerel? What is their optimum illumination? Why is the gathering effect of light under moonlight not so ideal? Why is the phototaxis so bad during the breeding season? With these problems in mind, we, together with our colleagues in Shanghai Institute of Physiology and East China Sea Fisheries Reserch Institute, made comprehensive studies on the phototactic character of the main marine pelagic fish such as round scads and chub mackerel with ethological, electrophysiological and visual-pigment-biochemical methods in the early 1970s. We also tested the new light sourse such as thallium indium lamp on the sea and achieved excellent results. Our achievements won the China National Science Conference Prize in 1978. Later we continued with our studies on the theory and application of the mechanism of phototaxis of fish and marine animals, vision physiology, and ethology. This paper gives a summary of the study in this field in China.

I. The Studies on Behaviourat Physiology:

He Daren, Yu Wentsao and others have studied the phototactic behaviour of round scad (Decapterus maruadsi), chub mackerel (Pneumatophorus japonicus), sardine (Sardinella perforata), silverside (Atherina bleekeri), needldfishes (Ablennes anastomella) Cardinal fish (Apogon lineatus), Mugil carinatus and squid (Loligo duvaucelii) with photogradient method; Zheng Meili, He Daren and others have

studied the behavioural physiology of cuttlefish (Sepiella maindroni) while Luo Huiming and others have studied that of young eel(Anguilla japonica) and swimming crab (Portunus trituberculatus). Their studies included threshold of reaction to light, optimum illumination, reaction to color light and the influence of background light on phototactic behaviour. The exposition of the above-mentioned characters of animals can provide scientific basis for the selection of the optimum artificial light source in production, the determination of effective attractive range and the calculation of gathering rate.

The major reaults are; The young fish and adults of round scad and chub mackerel show positive phototaxis under the horizontal photogradient of between 10^{-1}-10^{3} lx ; the phototaxis of young fish was stronger than that of adults; the optimum illumination of young chub mackerel was $10^{\frac{1}{2}}$-14 lx in water temperature of 24.5-27℃. In both single and group experiments, the results of response of chub mackerel are basically the same and the response of group experiment is even more stable.

We also did comparision experiments on needldfishes, cardinal fish and Mugil carinatus, the results are as follows; needlefish were always distributed in the relatively stronger illumination region of each series of photogradient; under the same condition, cardinal fish were constantly distributed in the relatively weaker illumination region of each series of photogradient; the phototaxis of the young fish and adults of round scad, chub mackerel, the young fish of Mugil carinatus remained between the former two. Chub mackerel and round scad both belong to the type of fish that show positive reaction to light but do not tend to the strongest light. When a comparison was made between these two, round scad showed

stronger phototaxis than chub mackerel. Therefore, both of the two fishes can be the objects of light fishing. The optimum illumination regions of squid and cuttlefish were 10^{-1}-10^{1} lx and 10^{-2}-10^{1} lx separately. Both belong to the type that tends to weak light. The optimum illumination of swimming crab was 10^{-3}-10^{-2}lx , with the growth development, the optimum illumination of young eels changed from 10^{-1}-10^{1}lx to 10^{-2}-10^{-1}lx . This shows that the character of phototaxis differs in different stages of development.

Some fish and marine animals can show selective response and color vision to color light. The study in this field is of great importance to light source color selection in production. Under dark adaptation, the phototactic rate of young and adult round scad to blue-green light is the highest while that to red light is the lowest. After the transition from dark to light adaptation, the phototactic rate to yellow-green light is the highest. Chub mackerel shows the highest phototactic rate to violet and red lights under both dark and light adaptations, while the peak value of its spectral sensitivity remains to blue and green lights. The author points out that the optimum light color is different from the sensitivity light color. The squid shows the greatest phototactic rate to blue light.

Moonlight, functioning as the background light, poses a practical problem in production that influences gathering effect. Our tests showed that background light invariably reduced the phototaxis of the above mentioned animals; the influence of background light could be restrained by increasing the light intensity of illumination; the background light had a stronger influence on the animals of weaker phototaxis than on those of stronger phototaxis. But exceptionally, within the range of 10^{1}-10^{3}lx , squids showed a higher phototactic rate with background light than without it. Such an unusual phe-

menon was associated with the sexual maturity and moonlight night reproduction of squids. Therefore, contrary to the common phototactic fish, the yield of squids can be raised if we fish with a hook and a line at moonlight night during their breeding season with properly increased light source intensity. Water temperature can influence the phototaxis of young round scads and increase their phototaxis within relatively lower optimum temperature range.

He Daren and others have also studied the feeding intensity of juvenile muttets (Mugil sp.) under different illumination and probed into the role of vision during fish's feeding. The results show that the illumination intensity has a very strong influence on the feeding intensity of mullet juvenile to daphnia, its feeding intensity reaches the maximum under the illumination of 10^2 lx ; the feeding rate reaches the highest under 10^2 lx and reaches the maximum within 20 minutes.

The peak of feeding activity of young mullet appears only under certain illumination condition and is closely related to the feeding activity under natural condition and circadian rhythm. Our tests have confirmed the important role of vision in their feeding activity and provided basis for determining the environmental brightness and bait quantity at the time of throwing in the bait.

Since 1984, He Daren and others have studied the optomotor reaction of fish. They studied the optomotor reaction characters of the young fish of grey muttets (Mugil cephalus), Perch (Lateolabrax japonicus), Porgy (Sparus latus), Carp (Cyprinus carpio), grass carp (Ctenopharyngodon idellus) etc successively. Liu Lidong, He Daren etc, have also made an overall study on the optomotor reaction of Nile tilapia and its influencing factors. Their study included the influences of environmental illumination, the screen speed of rota-

tion, water temperature, structure of visual field, body length etc. on the optomotor reaction of tilapia. They also described the characters of reaction of individual, population and monocular. It is shown that the young fish of this kind has typical optomotor reaction under the illumination of 10^{-5}-10^{4} lx . Within certain range, the optomotor reaction of fish enhances with rising environmental illumination and water temperature, declines with increasing screen rotation speed and body length. The fish reacts most effectively to black-and-white vertical stripes, less effectively to oblique stripes, and none to horizontal stripes. The reaction of optomotor reaction intensities with the increasing with and number of vertical stripes within certain range. There is no obvious difference in the reaction of individual and population. The reaction of monocular fish is evidently weaker than of normal-binocular one, and the former has obvious orientation. He Daren and Zhou Shijie have studied the sensibility of young prawn (Penaeus orientalis) to moving object and its relationship with environmental illumination. The have also studied they optomotor reaction of young porgy under the condition of colour light.

II. Electrophysiological studies,

For the past dozen years and more, much has been done in the field of electrophysiology of fish and other marine animal vision. As the phototactic character of fish is directly related to its vision function, the determination of the electro-activity of different levels of peripheral and central neurons is one of the ideal indexes in the study of physiology of phototaxis. The main work in China is to study the ERG character with rough electrodes. After an overall study on the ERG of round scad and chub mackerel, Young

Xiongti and others have found that their G had the character of the retina of mixed type, and had obvious off-response, and that its b-wave was highty sensitive to the oxye deficiency. Background light could noticeably raise the that hold of sensitivity of retina. This just corresponded to the result ethological study. Zheng Weiyun and others have found throuch their study on red grouper (Epinephelus akaara) that its retina has two photoreceptor system of rod and cone, but they have not found any typical character of mixed retina in the ERG. They belive that the cone of such fish has degenerated in certain degree and is adapted to weaklight vision without the ability of color discrimination. Yang Xiongli and others have determined the spectral sensitivity of the ERG b-waves of round scads and chub mackerel, and found that the peaks of spectral sensitivity curves of the two fishes under dark vision are 490 and 480nm respectively, the peaks of spectral sensitivity curves under light vision shift to 520 and 525nm respectively. They have also studied the induce potential of the tectum of chub mackerel. With the latent period of induce potential as the index, the spectral sensitivity curves thus obtained basicatly correspond with those under ERG dark vision. Therefore it is believed that the spectral sensitivity remains unchanged in the visual center. Zheng Weiyun, Chai Minjuan, Chen Zhong, Liu Lidong etc. have made studies on the ERG character of cuttle fish, swimming crab and prawn (Penaeus penicillatus)respectively, and showed that the ERG of these invertebrates are cornea negative wave one positive off-response. This is identical with the structure and arrangement of their retina. Through analysing the ERG spectral sensitivity of mud crab (Scylla serrata) under different adaptation, Yang Xiongli and others have suggested that its compound eye has only a single receptive system, and revealed the cir-

cadian rhythms of its ERG sensibility. They have also drawn an Aschematic diagram for control of circadian rhythmicity in the ERG of the crab. Chai Minjuan and others have made some comparative studies on the ERG circadian rhythms of several kinds of crustaceans (mud crab, tiger head crab (Orithyia mammillaris), swimming crab and prawn). In recent years, scientists of our country have also begun to study microelectrode. Yang Xiongli and others have recorded the horizontal cell potential of retina of the body of fresh water fish.

III. Studies on Biochemistry of Visual Pigment and Histology of retina.

As visual pigment forms the material basis of photoreception of retina, great importance has been attached to the study of it in the world. However, not much work has been done in the field of biochemistry of visual pigment.

Chen Ming and others have determined the rod visual pigment of round scad, chub mackerel, black carp (Mylopharyngodon piceus) grass carp silver carp (Hypophthalmichthys matitrix), bighead (Aristichthys hobilis), tilapia and so on. It is discovered that black carp, grass carp, silver carp and bighead are pigment of simple retinene2; the peak values of their spectral absorption are 530, 528, 525 and 527nm respectively; chub mackerel shows the pigment of retinene1 and the peak value of its absorption is 500nm; round scad containing two kinds of rhodopsin and their peak values of absorption are 488, 510nm respectively; tilapia contains the mixed pigment of retinene1 and retinene2 and their peak values of absorption are 500 and 522nm respectively.

Zheng Meili, Xiao Jinhua etc. have studied the histological structure of the retina of cuttlefish. Xu Yonggan, He Daren etc.