

Strengths and weaknesses in butterflyfish research: concluding remarks

Philip J. Motta

Department of Biology, University of South Florida, Tampa, FL 33620–5150, U.S.A.

In the last decade we have witnessed a vast increase in the number of scientific publications dealing with the chaetodontid butterflyfishes. Initially this research was primarily centered on their ecology and behavior but more recently the interests have broadened, as exemplified by this symposium. The interest in the group may be due to their conspicuousness, intriguing social behavior, circumtropical distribution, and the fact that they are one if not the most important fish predator on corals. With isolated groups of researchers scattered throughout the world interest was expressed in trying to get many of those involved together. With this intention I convened this symposium and charged each participant with a variety of responsibilities: they were to present their latest data on butterflyfish; they were encouraged to be speculative in though to provoke new areas for study in butterflyfish biology and perhaps fish biology; they were asked to relate their findings to other fish groups; and lastly they were asked to suggest avenues for future research in their areas. The symposium as a whole was also intended to point out areas of strength and weakness in butterflyfish research; to bring the researchers together in one meeting to discuss findings, coordinate efforts, and increase communication; and the scientific exchange was to be brought to the scientific community as a whole.

Our symposium participants, representing a significant portion of the butterflyfish research community, have had many fruitful hours of discussion. Resulting from these talks and presentations themselves I have taken the liberty of trying to summarize the findings.

First of all one notes that perhaps the greatest strength in chaetodontid research lies in the areas of feeding behavior and ecology, and secondarily social behavior. Timothy Tricas has addressed the

question of optimal foraging by quantifying the feeding habits of *Chaetodon multicinctus*. The energy content, handling time, and defense mechanisms of various stony corals all contribute to prey choice in this species. Darby Irons has approached feeding by studying time budgets for another species, the solitary *Chaetodon trifascialis*. Similar to the results of Thomas Hourigan, she has found that males and females feed at different rates. Among other things this calls into question the habit of lumping feeding rates for the separate sexes. Mireille Harmelin-Vivien has demonstrated the importance of food resources on the community structure and recruitment of butterflyfishes on coral reefs. The specialized obligate coral feeders begin benthic feeding at settlement and scleractinian polyps are the necessary exclusive food resource for recruits among these species.

To draw patterns in feeding behavior and ecology one needs baseline feeding studies, and Mitsuhiro Sano has classified the feeding habits of 32 species of Japanese butterflyfishes, making them probably one of the best understood butterflyfish assemblages in terms of their feeding. Scleractinian corals are the most important food resource for the Japanese butterflyfishes, and this and the many other feeding studies point out the importance of healthy coral reefs. Both Ernst Reese, Thomas Hourigan, and now Darby Irons provide evidence that butterflyfishes may be used as indicator organisms for assessing reef health. This strong link between corals and chaetodontid fish assemblages was also demonstrated by the work of Yolande Bouchon-Navaro and Claude Bouchon with their work in the Red Sea. They found significant correlations between the density of chaetodontid fishes and the diversity of the coral community.

The determinates of social systems in vertebrates

is an area of keen interest. Thomas Hourigan has used the butterflyfishes as model organisms and determined that the distribution and quality of food resources are the major determinants of group size and mobility, and therefore specific social systems. James and Muriel Findley on the other hand, investigate the relationships between butterflyfish species richness and circumtropical patterns in distribution. They found no evidence of density compensation in richer communities despite what community theory predicts, but at the level of islands and regions, habitat breadth diminishes as species richness increases. Ernst Reese has tackled a much neglected area of fish biology, orientation behavior of reef fishes. The coral feeding chaetodontids follow stereotyped routes in their foraging, foraging paths that are based on learned locations of route specific landmarks.

The study of butterflyfish larval distribution, recruitment, and reproduction has attracted much attention because of the intense interest in these areas for reef fishes in general. Like many reef fishes they are territorial or home ranging, and broadcast spawners. What therefore is the fate of their larvae, how are they recruited onto the reef, and what factors influence the abundance and distribution of the adults? Jeffrey Leis has reviewed all the available literature on their larval stages and found among other things that chaetodontid larvae are uncommon in the plankton. Unexplainably, waters near reefs have the fewest larvae. Both size and age at settlement vary widely within the family and within the genus *Chaetodon*. Both Phillip Lobel and Patrick Colin describe spawning behavior. Lobel describes how intruders sneak spawns in one species *Chaetodon multicinctus*, and Colin reviews the literature on spawning among five western Atlantic species. He finds that smaller species may adopt the strategy of producing moderate numbers of eggs per day over a spawning season of at least a few months, while larger species may produce more eggs per day for a shorter period.

Remarkably, the systematics and biogeography of the butterflyfishes are sorely understudied, perhaps because it represents such monumental effort to analyse worldwide patterns. With the monograph of Burgess the biogeography and systematics

of butterflyfishes have begun to be understood. Stanley Blum uses the most extensive cladistic analysis of the butterflyfishes to identify a set of vicariant events that have generated nearly a third of the present species diversity and he presents the geography of the inferred barriers.

Perhaps because the adaptive significance of coloration is so difficult to test there have been so few studies on this subject, for fish and other vertebrates. Butterflyfishes are often cited as examples of animals with bright or 'poster' coloration. The hypotheses have been numerous, as reviewed by Stephen Neudecker, but until now few conclusions have been drawn. Neudecker deduces that the primary selective force behind this bright coloration, particularly eyespots, has been predation, and color patterns in these fishes minimizes this threat and communicates social information.

The anatomy and physiology of butterflyfishes is another area of neglect. I have tried to pull together my data on the dentition of fifteen Pacific and western Atlantic species and relate this to the phylogeny of the group as presented by Stanley Blum. Despite what appears to be adequate time for evolution between the two faunas, many of the species retain the generalized tooth arrangement. However, as a whole the Pacific species show more specialized morphologies for hard coral feeding than do the western Atlantic species. Roland Bauchot, Thomot Athanase, Jean-Marc Ridet, and Marie-Louise Bauchot have presented the most comprehensive studies on butterflyfish central nervous systems and sensory systems. The eye muscles and their innervation are described in *Chaetodon trifasciatus* and related to their ecology, as is the membranous labyrinth and their precise locomotory aptitudes. Lastly, they present a comprehensive comparison of the brain of pomacanthids and chaetodontids, and speculate on the relationship to feeding in both families.

Now that we have presented some of our strengths what then are the weaknesses in our study of the butterflyfishes. We obviously know very little about the fate of their larvae and the life span prior to adulthood. How do juvenile butterflyfishes compete for space and food on the reef? There are almost no ontogenetic studies on butterflyfishes.

Are the social systems of the juveniles different from the adults, and how, and what factors influence their social systems? Similar to many other reef fishes we know very little about ontogenetic changes in morphology, in diet and feeding. We also know little about the recruitment processes of reef fishes and butterflyfishes in specific, as witnessed by the continuing debate about these processes.

The biogeography of this family is still not completely understood even though the distribution is quite well documented. We have also just begun to explore the peculiarities of the nervous and sensory systems as well as the functional morphology of the group as a whole. Pulling an example from my own work one notes that up until quite recently ichthyologists described butterflyfishes by their simple brush-like teeth, implying the dentitions were essentially alike. The groundwork of Warren Burgess and later myself demonstrated that simply because the teeth are small does not imply they are identical. Examining only ten species I have described a range of specializations in the dentition

and jaw morphology. Where does it end? Each researcher can provide a plethora of avenues for continued studies, as they did at the end of every paper. In that respect we have accomplished another one of our intended goals. We have strengthened the base of our understanding of the group, contributed to the understanding of the coral reef fish community, and provided direction for future studies on these fishes.

Finally, this symposium has brought chaetodontid researchers together in person and in publication. There can only be greater communication and exchange from here on, and at the very least the published volume should serve as a communal source of scientific information on the group. Oftentimes such specialized symposia are unfortunately viewed with skepticism. But apart from all the aforementioned benefits, this symposium was the catalyst for seventeen publications involving twenty scientists. Similar symposia focusing on specific fish taxa should be encouraged and supported.

