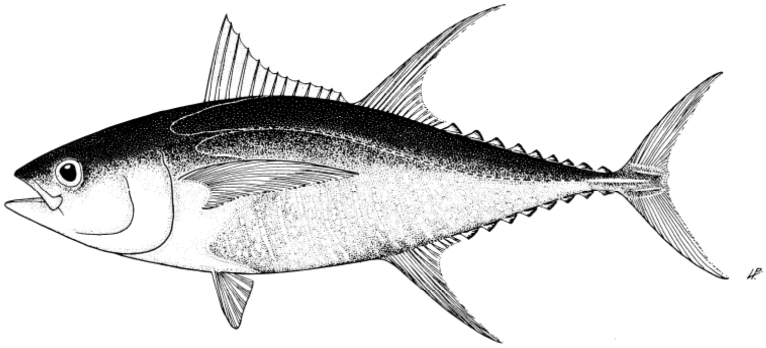
16th Meeting of the Standing Committee on Tuna and Billfish

SCTB 16
Mooloolaba, Qld, Australia
9-16 July 2003

SCTB16 Working Paper

YFT–7

THE BIOLOGY OF FAD-ASSOCIATED TUNA: TEMPORAL DYNAMICS OF ASSOCIATION AND FEEDING ECOLOGY



Kim Holland, Dean Grubbs, Brittany Graham, David Itano, and Laurent Dagorn[1]

Pelagic Fisheries Research Program
Joint Institute of Marine and Atmospheric Research
University of Hawaii

[1] Institute for Research and Development (IRD)
France

July 2003

The Biology of FAD-associated Tuna:
Temporal Dynamics of Association and Feeding Ecology

Kim Holland, Dean Grubbs, Brittany Graham, David Itano, and Laurent Dagorn[1]

Pelagic Fisheries Research Program, JIMAR/SOEST
University of Hawaii
[1] Institute for Research and Development (IRD)
France

Introduction

This report presents preliminary results and data analysis of several inter-related projects that are focused on elucidating the biology of FAD-associated yellowfin and bigeye tuna. Of particular interest are the temporal dynamics of the associative behaviour ('residency' duration, arrival and departure times, movements between FADs, etc.) and the feeding ecology of tunas found in association with FADs in Hawaiian waters. One key question concerning the association of tunas with anchored FADs is whether or not this behaviour impacts the feeding ecology of the tuna associated with the FAD. Conceptually, association with a moored FAD could have positive or negative impacts on feeding success but there is growing concern that this behaviour is a maladaptive trait that has been transferred from a behaviour that evolved in natural settings (association with drifting debris or other structures such as seamounts). As a sub-set of a wider ranging study of tuna feeding ecology, we have focused on analysing the dietary overlap and foraging success of yellowfin and bigeye tuna caught in association with nearshore and deep water moored buoys. Duration of association ("residence times") and inter-FAD movement are of interest because they give insight into the impact of FADs on the overall distribution of the resource and also into the level of vulnerability to fishing that results from their association with a fixed FAD.

Data presented here were obtained using three different techniques; gut content analyses, isotope ratio analyses and sonic telemetry and pertain only to anchored FADs. All aspects of the work were funded by grants from the Pelagic Fisheries Research Program, University of Hawaii. The data presented here are preliminary and data collection and analysis are ongoing. This report should not be cited without permission from the authors.

Methods

Sonic Telemetry. Vemco VR2 hydrophone receivers/data loggers have been installed on all the thirteen moored FADS surrounding the island of Oahu, Hawaii (www.hawaii.edu/HIMB/FADS). The data loggers are attached to the FAD mooring line at a depth of approximately 20 meters and are periodically retrieved and the stored data downloaded. Field-testing indicated that Vemco V16 acoustic transmitters could be reliably detected at a range of approximately 500 meters. Field-testing also revealed that the presence of multiple transmitters could cause "collisions" that result in loss of detection of some pingers for significant periods of time. We are taking this into consideration in setting our analysis parameters for "residency".

Vemco V16 acoustic transmitters have been placed intraperitoneally in approximately 75 bigeye and yellowfin tuna (55 – 120cm FL) that were caught, instrumented and released at seven of the Oahu FADs. Ten fish were double tagged with Vemco acoustic transmitters and MK9 archival tags supplied on a collaborating basis by Wildlife Computers. Approximately 15% of tagged fish have been recovered including two double-tagged yellowfin (one acoustic transmitter has been used in four fish – i.e., has been recaptured and re-used three times!)

Trophic Ecology – Dietary studies. The primary sites of interest are four offshore NOAA weather buoys, the Cross Seamount, and the array of nearshore moored FADs. Gut samples have been obtained by placing observers on commercial fishing vessels and from port sampling (either on the vessel or from the fish auction). Fish associated with nearshore FADs have primarily been acquired through the use of our own research vessel. To date, we have collected more than 1,500 samples. Bigeye and yellowfin are equally represented. Sixty percent of bigeye tunas sampled were collected at the Cross Seamount, while 24% were captured near offshore weather buoys, 6% were associated with nearshore FADs around Oahu, and 10% were unassociated. By contrast, fifty-nine percent of yellowfin tunas sampled were caught in association with the nearshore FADs, while 23% were associated with the Cross Seamount, 12% were associated with the offshore weather buoys, and 6% were unassociated.

Gut contents are being analysed both in terms of dietary overlap (i.e., what types of food are being eaten at the different aggregation sites) and in terms of feeding ‘success’ as measured by stomach fullness and the number of prey items per stomach.

Trophic Ecology – Isotope Analyses. Analysis of the ratios of stable carbon and nitrogen isotopes is proving to be a powerful new tool for investigation of the trophic status and feeding history of a wide range of species. We are now applying these techniques to tuna. We are at the early stages of this research and only a small subset of preliminary data pertaining to FAD-associated fish will be presented in this report. A range of tissues (white muscle, red muscle, liver, hard parts, etc.,) are being analyzed in an attempt to discern both the current and historical trophic status of tuna taken from FADs in Hawaiian waters.

Results

Sonic Telemetry. We are still deploying acoustic tags in FAD-associated fish and the results presented here will undoubtedly change as more data are collected and analysis techniques are modified. However, some results are consistent. Among these is the fact that the current long-term monitoring data are confirming earlier results that were obtained through active sonic tracking. Specifically, there appear to be two categories of commonly occurring FAD-associated behaviour – 1) animals that briefly visit the FADs and intersperse visits with off-FAD excursions of various durations and 2) animals that are constantly associated with the FADs for periods of many days or even a few weeks. We will be analysing our data to specifically discern if these two types of behaviours are always displayed by different fish or whether or not an individual fish can display both types of behaviour.

Analysis of arrival and departure times indicate that, for both species, fish tend to leave the FAD throughout the day and night but that yellowfin mostly arrive at the FAD at night whereas bigeye tend to arrive at dawn and dusk.

Gut contents. Gut content data indicate that both bigeye tuna and yellowfin tuna use generalized feeding strategies to exploit extremely diverse forage bases. We have identified more than 90 families of organisms that are prey for yellowfin tuna and more than 100 families that are prey for bigeye tuna. The prey taxa differ significantly as a function of association. That is, tuna feed on different prey types when they are associated with a seamount, a nearshore FAD, an offshore FAD, or when they are unassociated. Interestingly, bigeye tuna and yellowfin tuna feed on distinctly different prey taxa as well (as indicated by estimates of dietary overlap) even when they co-occur at the same aggregation site (Table 1). Bigeye tuna generally occupy deeper waters than yellowfin tuna, though both species are commonly caught near the surface when associated with FADs. Our data suggest that the separation in vertical distribution is maintained during feeding. Yellowfin tuna feed primarily on epipelagic prey associated with the shallow mixed layer while bigeye tuna feed on mesopelagic prey associated with the deep scattering layer. This pattern is exhibited for unassociated fish as well as those associated with nearshore FADs, offshore FADs, or the Cross Seamount.

Dietary Overlap

Percent Overlap

Yellowfin

Bigeye	Unassociated	Seamount	Weather Buoy	FAD
Unassociated	4.3%	12.6%	3.3%	2.4%
Seamount	3.8%	52.1%	12.7%	36.8%
Weather Buoy	9.2%	29.4%	12.1%	7.8%
FAD	9.1%	19.8%	13.1%	33.0%

Morisita's Index of Overlap

Yellowfin

Bigeye	Unassociated	Seamount	Weather Buoy	FAD
Unassociated	0.02	0.10	0.00	0.03
Seamount	0.02	0.54	0.22	0.5
Weather Buoy	0.11	0.21	0.16	0.04
FAD	0.04	0.13	0.07	0.22

Table 1: Dietary overlap between bigeye tuna and yellowfin tuna by association. None of the comparisons are significant. (Percent overlap is significant at 60% and Moriseta' index is significant at 0.6.)

Gut content data suggest that feeding success is similar for unassociated bigeye and yellowfin tuna (Figure 1). These data also suggest that there are distinct and consistent differences in the feeding success of yellowfin tuna and bigeye tuna when they are associated with man-made FADs or the Cross Seamount. Feeding success for yellowfin tuna was comparable between unassociated samples and those from the seamount and offshore anchored FADs (>3000 m depth), but elevated on the nearshore anchored FADs (<900 m depth). For bigeye tuna, conversely, feeding success was highly elevated on the seamount, but extremely depressed on the nearshore and offshore anchored FADs. This may be due to the fact that, in general, bigeye feed on deeper organisms and certain seamounts provide an enriched source of these mesopelagic prey, which are largely absent from the anchored surface FADs.

To investigate the affect of tuna size on these patterns, we divided tuna samples into four 25-cm intervals based on fork length (<50 cm, 51-75 cm, 76-100 cm, >100 cm). The majority of samples from the nearshore FADs were from small tuna (<75 cm fork length) while most fish from the offshore FADs were larger (>75cm fork length). When associated with nearshore FADs, feeding success for yellowfin was elevated for all size classes. On the offshore FADs, however, feeding success was elevated for the largest size class (>100 cm) but depressed for all smaller size classes. The feeding success was very low for all size strata of bigeye tuna on all FADs.

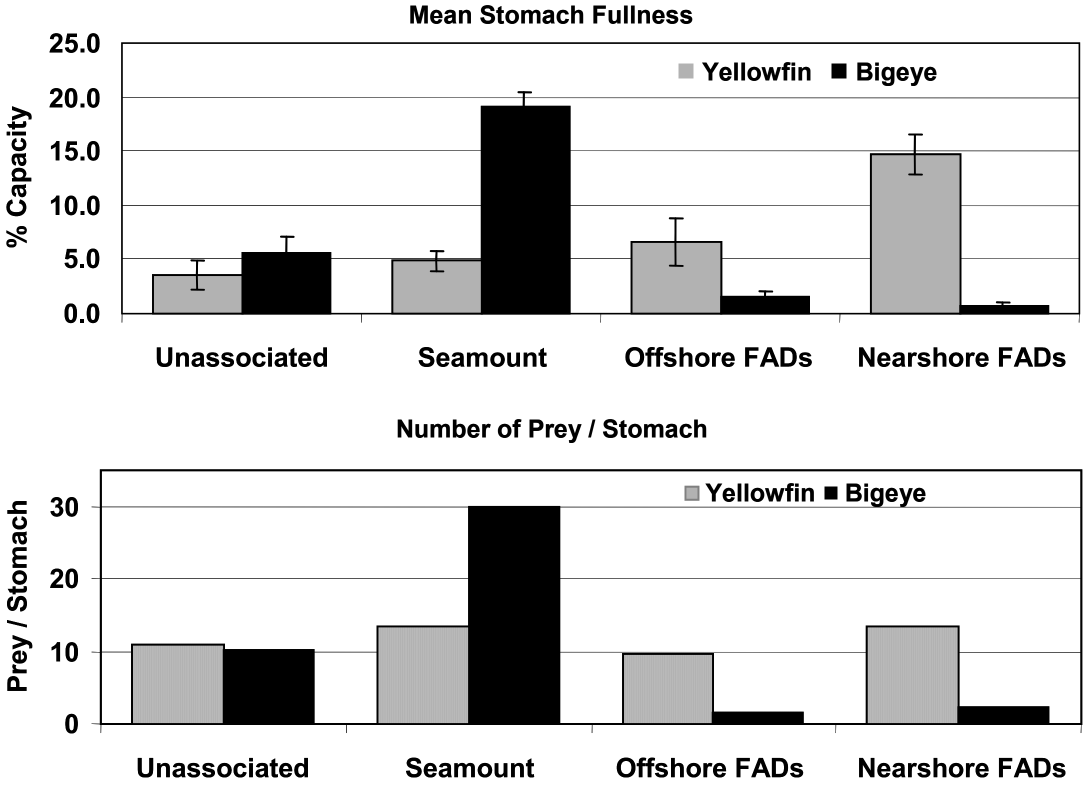


Figure 1: Mean stomach fullness (%capacity) and mean numbers of prey per stomach for bigeye and yellowfin tuna as a function of association.

Isotope analyses. Isotope analyses of yellowfin and bigeye tuna caught at FADs indicate that a shift in feeding ecology may be occurring at sizes between 40 and 50 cm FL (Figure 2). That is, a shift in feeding ecology may be occurring when fish reach about 45 cm FL. These data are remarkable in that shifts in isotope signatures are usually more gradual and not as abrupt as demonstrated in our results. If these data hold up with an expanded sample size, these results could be a major insight into underlying biological mechanisms involved with previously hypothesized changes in natural mortality for different size classes. The change in isotope signature at 40-50 cm is corroborated by the gut content data that show a change in diet at this same size (Figure 3). Specifically, the prey of FAD-associated yellowfin tuna that are smaller than 45 cm FL consists primarily of larval stomatopods (mantis shrimp), while the diet of larger FAD-associated yellowfin tuna is dominated by adult *Oplophorus gracilirostris*, a mesopelagic shrimp that resides below 300 meters during the day but migrates to within 50 meters of the surface at night.

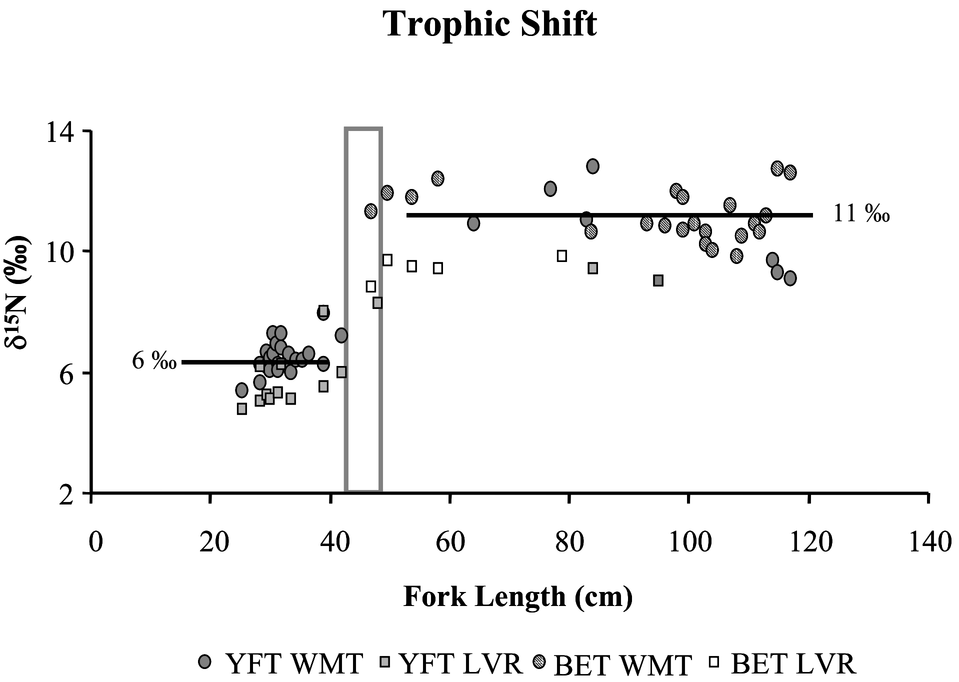


Figure 2: Rapid ontogenetic shift in trophic level of FAD-associated tuna based on nitrogen isotope values.

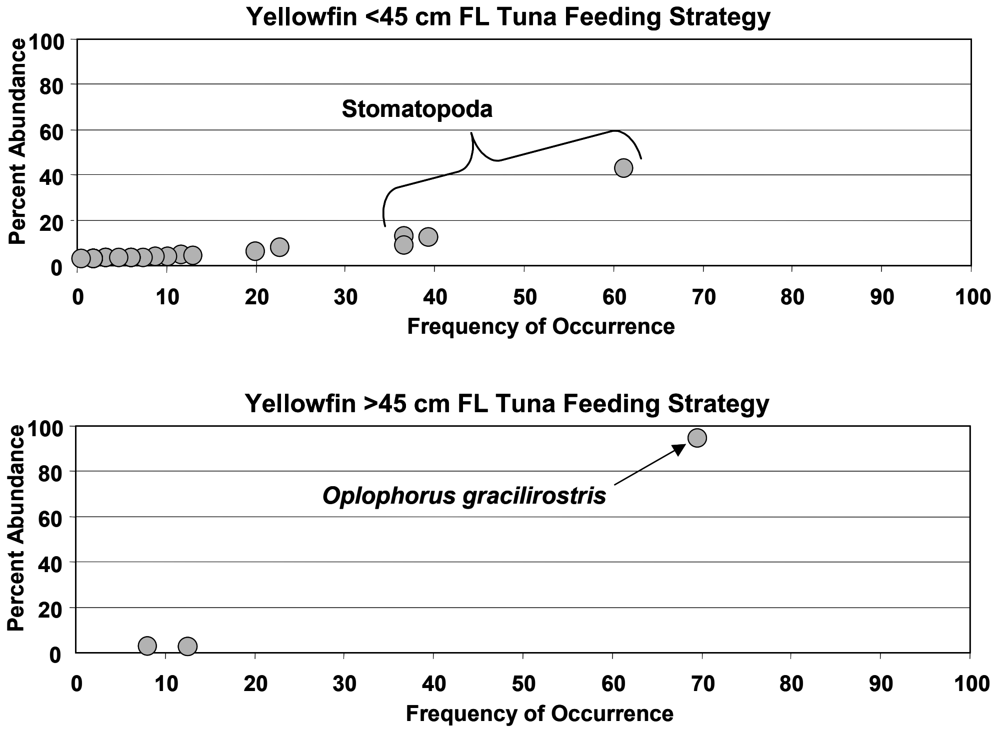


Figure 3: Ontogenetic shift in diet of juvenile yellowfin tuna associated with nearshore FADs. Primary diet of tuna less than 45cm fork length consists of larval stomatopods while adult oplophorid shrimp dominate the diet of the larger tuna.

Also, there appears to be a difference in the isotope signatures of similarly sized yellowfin and bigeye. That is, in sizes > 50 cm, bigeye tuna appear to occupy a higher trophic stratum than yellowfin tuna of similar size. Further data collection and analysis testing will be necessary to confirm these interpretations. A tantalizing result was obtained from one set of fish collected from a near-shore FAD on a single day (Oct 2, 2002). When compared with all other fish of similar size, these fish showed elevated nitrogen isotope values (Figure 4). It is possible that this signature is the result of a starvation event. That is, this could be a school of fish that recruited to the buoy following a period of poor feeding. We intend to test this hypothesis with forthcoming experiments with captive tuna.

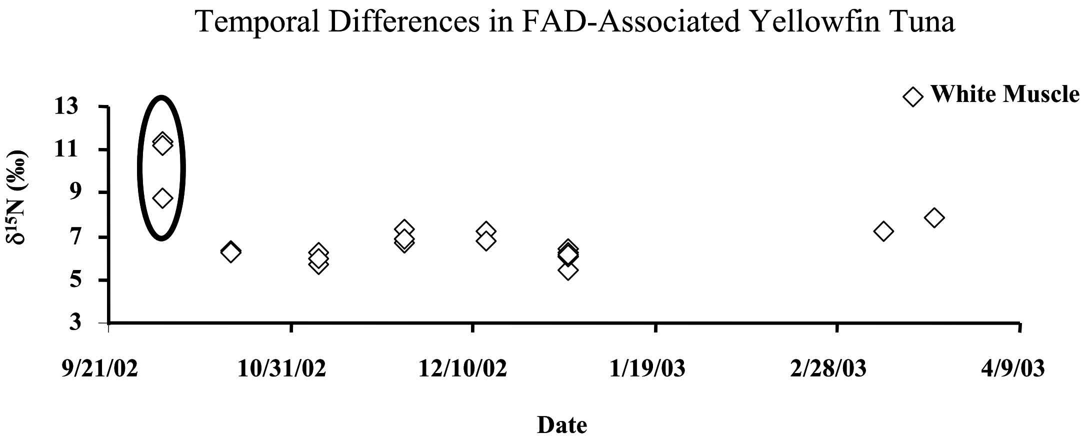


Figure 4: Nitrogen isotope values for juvenile yellowfin tuna associated with nearshore anchored FADs. The elevated δ^{15}N values in the first subset of samples may indicate starvation.

Discussion

The various components of these ongoing FAD-related experiments are yielding consistent and inter-related results. FADs do appear to have a significant impact on the horizontal and vertical movements of these species and these are reflected in their feeding ecology when the fish are at the FADs. The gut content data suggest that associating with the Cross Seamount may impart a significant trophic advantage to bigeye tuna but may offer little or no advantage to yellowfin tuna. In contrast, associating with anchored FADs may have little trophic impact on yellowfin tuna but may be metabolically costly to bigeye tuna. The mesopelagic forage the bigeye tunas typically feed on is largely absent around these structures and they do not appear to switch to the available epipelagic forage. Gut content and isotope analyses of feeding behaviour and trophic status are yielding consistent results and both avenues of investigation point to a significant shift in feeding behaviour of yellowfin tuna around 45-50 cm. This size class of fish is a major component of FAD assemblages and future work will attempt to document their FAD- related behaviour using the acoustic transmitter monitoring system that is proving so successful with the larger fish in the current experiments.