JIMAR – PFRP ANNUAL REPORT FOR FY 2006

P.I. Names: Valerie Allain, Robert Olson, Felipe Galván-Magaña, and Brian Popp.
Collaborator: Brian Fry.
Graduate Student: Brittany Graham

Project Proposal Title: Trophic structure and tuna movement in the cold tongue-warm pool pelagic ecosystem of the equatorial Pacific. JIMAR Project # 659559.

Funding Agency: NOAA

NOAA Goal:

- ☒ To protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management
- ☒ To understand climate variability and change to enhance society's ability to plan and respond
- ☐ To serve society's needs for weather and water information
- ☐ To support the nation's commerce with information for safe, efficient, and environmentally sound transportation

1. Purpose of the project:

Previous modeling suggests that tuna productivity in the western and central Pacific Ocean is tied to upwelling along the equator in the central and eastern Pacific. This project proposes to test this hypothesis by combining diet analysis, stable isotopic analyses, and food-web modeling to study trophic-level variation and tuna movements in the equatorial Pacific. Our hypothesis predicts that tunas that reside near equatorial upwelling regions feed at relatively low trophic levels. Opposite trends are expected in equatorial regions with little upwelling, such as the warm pool of the western Pacific, where tunas are expected to feed at higher trophic levels and move extensively, searching for less-abundant prey. The main objectives of the project are to define the trophic structure, establish an isotope-derived biogeography, and characterize large-scale tuna movements in the pelagic western, central, and eastern tropical Pacific. Results of this study should help define ecosystem linkages leading to tuna production and the effect of climate variability on the systems. This information is important for both fisheries production and ecosystem modeling of the equatorial Pacific Ocean.

2. Progress during FY 2006:

2.1 Sampling and stomach content analysis:

In the western and central Pacific, since the beginning of the project, 90 sampling trips on tuna fishing vessels have been completed. Of the 3140 stomachs collected so far from about 66 species, 2531 have been examined in the laboratory. Samples from two new areas, the EEZs of Wallis & Futuna and Fiji, have been collected.

In the eastern Pacific, fauna from 272 sets made during 64 trips on tuna purse-seine fishing vessels have been sampled since the beginning of the project. Samples of stomachs, muscle, and liver tissues have been collected from more than 10,700

specimens of about 47 taxa. The majority of the stomach samples have been partially or completely analyzed in the laboratory. The diet data from 53 trips are being analyzed by two students at CICIMAR, Mexico, and for 11 trips by students in Manta, Ecuador (all supervised by F. Galván).

2.2 Stable isotope and mercury analyses

Since the beginning of the project, ~2800 samples have been isotopically analyzed; the $\delta^{15}N$ and $\delta^{13}C$ of ~1700 samples were determined during FY2006. Our isotope dataset for the equatorial Pacific shows spatially-explicit patterns of trophic dynamics for tropical tunas in the pelagic ecosystem (Graham *et al.* 2006b). If a predator migrated extensively throughout these regions, then little geographical isotopic variation would be expected because regional $\delta^{15}N$ differences would be integrated over space and time. $\delta^{15}N$ spatial variability is high (12‰) for the tropical tunas, implying these species exhibit a surprisingly high level of regional residency. Species-specific $\delta^{15}N$ maps are a powerful tool to examine differences in trophic ecology and migration between species (see Graham *et al.* 2006b).

Stable isotope analysis of mesozooplankton samples, comprised by copepods, amphipods, euphausiids, and chaetognaths, was conducted during FY2006. Gladis Lopez, Ph.D. student at CICIMAR, Mexico, was instructed in stable isotope analysis of the zooplankton samples at the University of Hawaii, Stable Isotope Biogeochemistry Laboratory. Bulk $\delta^{15}N$ values of mesozooplankton exhibited the same geographical trend as the $\delta^{15}N$ values of bulk white muscle tissue (WMT) of yellowfin tuna (see next paragraph), providing further evidence that the geographical variability we are observing is due to variability in the $\delta^{15}N$ at the base of the food web. Bulk $\delta^{15}N$ values of yellowfin WMT and mesozooplankton were compared to derive estimates of yellowfin trophic level over a range of latitudes in the ETP, and the estimates agreed well with trophic level estimated by other methods (see next paragraph).

We have also analyzed the nitrogen isotopic composition of individual amino acids in yellowfin tuna samples from the ETP (see Graham *et al.* 2006b). We used the $\delta^{15}N$ of individual amino acids to distinguish changes in the $\delta^{15}N$ at the base of the food web from changes in the trophic level of yellowfin tuna from the ETP. The $\delta^{15}N$ of bulk WMT increased by about 5‰ from 10ºS to 25°N in the ETP and can be attributed to variations in yellowfin trophic level and/or to changes in the $\delta^{15}N$ at the base of the food web. The $\delta^{15}N$ of essential amino acids (EAA) and nonessential amino acids (NAA) in tuna parallel the change in the $\delta^{15}N$ of bulk WMT, indicating that the observed trend of increasing ^{15}N enrichment with increasing latitude is due to changes in $\delta^{15}N$ at the base of the food web. Tuna trophic level estimated from the difference between the $\delta^{15}N$ of EAA and NAA (4.5±0.1) compares favorably with trophic level estimated by the difference between the $\delta^{15}N$ of yellowfin and mesozooplankton (4.2±0.4), and by previous yellowfin diet analyses (4.6-4.7). Our results set the stage for the application of compound-specific stable isotope techniques to support ecosystem-based approaches for the management of pelagic tuna fisheries.

Thirty-six samples of pelagic predators were submitted to B. Fry for sulfur isotope ($\delta^{34}S$) and total mercury (THg) analyses. Preliminary $\delta^{34}S$ data supports the ontogenic trophic shift observed in juvenile yellowfin tuna collected around Hawaii (Graham *et al.*

2006a) and, therefore, could help to distinquish foraging depth of pelagic predators. THg data is pending and will eventually be coupled with our existing THg dataset.

2.3 Modeling and diet analyses:

The diet data for skipjack, albacore, yellowfin, and bigeye tunas from the warm pool (equatorial western Pacific) have been partially analyzed. The diets of the four tunas show relatively low overlap, and are differentiated by the tunas' vertical distribution and behavior. Skipjack eat only epipelagic prey, mainly fishes, with a very high cannibalism rate and low prey diversity. Yellowfin also eat mainly surface prey, but also some deep organisms. Bigeye and albacore have high percentages of deep-dwelling prey in their diets. The diets of skipjack and yellowfin, and of albacore and bigeye, are often similar taxonomically, but are different in terms of prey size.

Work to develop an ecosystem model, based on Ecopath with Ecosim (EwE), for the western Pacific has continued. Diet data were included for six forage components, following the SEAPODYM model, which are based on their depth distribution and vertical migratory behavior. Although an improved model could not be obtained, the work was useful for furthering our understanding of the ecosystem and highlighting some factors and groups that need better parameterization.

The diet data for 37 tunas and associated species from the cold tongue (equatorial eastern Pacific) have been partially analyzed. The data reveal significant predation by sharks, wahoo, and barracuda on juvenile tunas. Cephalopods, especially jumbo squid, are a key prey item for several predators, supporting the concept that squid are a keystone prey in the pelagic ecosystem. Several small fishes that associate closely with floating objects, such as triggerfish, kyphosids, lobotids, and mackerel scad, feed on algae, gastropods, and crustaceans that live on or near the objects.

The current EwE model for the pelagic ecosystem of the eastern Pacific will be reformulated based on new diet and stable isotope data from this project. These data are being compiled as more samples are analyzed.

A preliminary comparative study was carried out using diet data for skipjack, yellowfin, and bigeye tunas from the eastern and western Pacific. The fish caught by different fishing gears had different diets. The tunas caught by longline had a higher diversity of prey than tunas caught by purse seine. Longline and purse seine sets target different size tuna at different times of the day and at different depths. Differences in the diet descriptions from the two sampling gears need to be clarified, and stable isotopes are promising for this purpose.

3. Plans for the next fiscal year:

This 3-year project was scheduled to finish at the end of 2005. However, the labor-intensive sample collection and the time-consuming lab work have not given us sufficient time to fully exploit our extensive and unique dataset. In December 2005 the project received a time extension to October 31, 2006 and will be receiving additional PFRP funding during calendar year 2006. For now, sampling efforts have been terminated. The project extension will be dedicated to processing the remaining samples in the laboratory, data analysis, modeling, and publication of the results.

In the western and central Pacific, thanks to the additional PFRP funding for the project extension, two lab assistants will examine the remaining stomach samples. Diets of the main predators from this region will be analyzed and compared to the results from the eastern Pacific. The diet information will also be incorporated into an Ecopath model for the western and central Pacific. Stomach contents analysis of the diverse suite of predators collected in the eastern Pacific will continue. The diet information will form the basis for the graduate students' dissertation and thesis, will be synthesized into peer-reviewed publications, and eventually incorporated into a new Ecopath model for the eastern Pacific.

Compound-specific nitrogen isotope analyses of amino acids will be used to investigate a) the processes producing anomalous ^{15}N enrichment in bulk yellowfin tuna collected from Micronesia and French Polynesia, b) the effects of tissue catabolism during fasting on bulk $\delta^{15}N$ values of Oahu FAD-associated juvenile yellowfin tuna, c) the constancy and the mechanisms underlying the 7‰ per trophic level difference between the $\delta^{15}N$ of glutamic acid ("trophic transfer" amino acids) and the essential amino acids ("source" amino acids) using the distinct positive shift in the $\delta^{15}N$ of Oahu FAD-associated yellowfin tuna documented by Graham *et al*. (2006), and d) potential effects of commercial fishing on the trophic ecology of pelagic fishes in the eastern Pacific inferred from changes in trophic level based on the $\delta^{15}N$ of individual amino acids in archived fish tissues.

Further analysis of the trophic ecology of several key predator components of the pelagic ecosystem in the ETP will be investigated using comparisons with the geographical distribution of bulk $\delta^{15}N$ values of mesozooplankton and mesopelagic myctophid fishes, as proxies for the base of the food web. Plans include developing a model (*e.g.* GLM) to predict and map large-scale spatial patterns. Independent variables will include spatial and environmental factors.

Several papers for the different regions and comparative papers on diet and isotopes for the entire equatorial Pacific will be submitted for publication. Final results of the project will be presented during the Hawaii PFRP-PI meeting in November 2006.

4. Papers published in refereed journals during FY 2006:

Graham B. S., Grubbs D., Holland K. and Popp B. N. (2006a) An ontogenic dietary shift in juvenile yellowfin tuna from Hawaii, Marine Biology (in press).

Popp B. N., Graham B. S., Olson R. J., Hannides C. C. S., Lott M. J., Lopez-Ibarra G. A., Galván-Magaña F. and Fry B. (2006) Insight into the trophic ecology of yellowfin tuna, *Thunnus albacares*, from compound-specific nitrogen isotope analysis of proteinaceous amino acids. In Dawson T. and Siegwolf R. (eds) Isotopes as Tracers of Ecological Change, Elsevier Academic Press (submitted).

4.1. Papers in preparation for refereed journals:

Allain V. *et al. In Prep.* Gear effect (Longline vs. Purse seine) on the diet description of tropical tuna in the western Pacific incorporating stomach content examination and stable isotope mixing model.

Graham, B.S. *et al. In Prep.* Tissue turnover rates calculated from captive and wild yellowfin tuna, *Thunnus albacares*: implications for using chemical tags in migration studies.

Olson, R. J. *et al. In Prep.* Trophic position of yellowfin and bigeye tuna in the pelagic eastern Pacific Ocean predicted from stable isotopes and food habits

5. Other papers, technical reports, meeting presentations, etc:

5.1. Other papers:

Allain, V. 2005. Ecopath model of the pelagic ecosystem of the western and central Pacific Ocean. EB WP-10. WCPFC First Scientific Committee. Nouméa, New Caledonia. 8-19 August 2005. 19 pp.

Allain, V. 2005. Diet of large pelagic predators of the western and central Pacific Ocean. BI WP-2. WCPFC First Scientific Committee. Nouméa, New Caledonia. 8-19 August 2005. 18 pp.

Allain, V. 2005. What do tuna eat? SPC Fisheries Newsletter. 112: 20-22.

Graham, B., R. Olson, B. Fry, B. Popp, V. Allain and F. Galvan-Magana. 2006b. The new PFRP tag: Using stable isotope techniques to better understand the trophic ecology and migration patterns of tropical tunas. PFRP Newsletter, v. 11, April-June 2006.

5.2. Technical reports:

None

5.3. Meeting presentations:

Allain, V. 2005. Ecopath model of the pelagic ecosystem of the western and central Pacific Ocean. EB WP-10. WCPFC First Scientific Committee. Nouméa, New Caledonia. 8-19 August 2005.

Allain, V. 2005. Diet of large pelagic predators of of the western and central Pacific Ocean.. BI WP-2. WCPFC First Scientific Committee. Nouméa, New Caledonia. 8-19 August 2005.

Allain, V., B. Graham, R. Olson, B. Popp, F. Galván-Magaña, and B. Fry. 2005. Tuna trophic structure in the Pacific Ocean. PFRP PI Workshop. Hawaii. 14-18 November 2005.

Fry, B., N. Cormier, A. Demopoulos, and B. Graham. 2006. Adventures in Isotopia, the wide Pacific and Beyond. Invited Seminar at the Univ. of Wisconsin, Milwaukee. April 2006.

Graham, B., B. Popp, V. Allain, R. Olson, F. Galván, R. Humphreys, and B. Fry. 2005. Biogeography and trophic dynamics of billfish collected in the equatorial Pacific Ocean as determined by stable isotope analysis. 4th International Billfish Symposium. Catalina Island, CA. October 2005.

Graham B., B. Fry, B. Popp, V. Allain, R. Olson and F. Galvan-Magana. 2005. Isotope biogeography: A novel approach to studying pelagic predators in the equatorial Pacific Ocean. PFRP PI Workshop. Hawaii. 14-18 November 2005.

Hannides, C. and B. Graham. 2006. Linking top down and bottom up: the application of amino acid-specific stable isotope analysis in (sub)tropical ecosystems. UH Department of Oceanography, Biogeochemistry Brown Bag Seminar. April 2006.

Olson, R., B. Graham, F. Galván-Magaña, B. Popp, V. Allain and B. Fry. 2005. Trophic structure in the pelagic eastern tropical Pacific Ocean: progress based on stable isotopes and diets. 56th International Tuna Conference, Lake Arrowhead, California. 23-26 May 2005

Olson, R., B. Graham, F. Galván-Magaña, B. Popp, V. Allain and B. Fry. 2005. Seeking trophic clarity: Linking stable isotopes and stomach contents in the pelagic eastern Pacific Ocean. PFRP PI Workshop. Hawaii. 14-18 November 2005.

Popp, B. N. 2005. Insight into tuna trophic level and physiology from compound-specific nitrogen isotope analysis of proteinaceous amino acids. PFRP PI Workshop. Hawaii. 14-18 November 2005.

Popp B. N., Olson R. J., Graham B. S., Hannides C. C. S., Lott M. J., Lopez-Ibarra G. A. and Galván-Magaña F. 2006. Insight into the Trophic Level of Yellowfin Tuna, *Thunnus albacares*, from Compound-Specific Nitrogen Isotope Analysis of Proteinaceous Amino Acids, BASIN-SIBAE Meeting "Isotopes as Tracers of Ecological Change" March 13-15, 2006, Tomar, Portugal.

6. Graduates:

No students have graduated.

7. Awards:

B. Graham received a 4th International Billfish Symposium Travel Grant Award

B. Graham received a UH GSO Travel/Research Award

8. Publication Count:

	JL Lead Author			NOAA Lead Author			Other Lead Author		
	FY04	FY05	FY06	FY04	FY05	FY06	FY04	FY05	FY06
Peer-reviewed									2
Non-peer reviewed							2	3	4

9. Students and Post-docs:

Brittany Graham. Ph.D. Candidate, Department of Oceanography, University of Hawaii. Ms. Graham is supported by a PFRP graduate assistantship and is in her 4th year of the program.

Noemi Bocanegra-Castillo. Ph.D. Candidate, Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, La Paz, B.C.S, Mexico. Working with diet data of fishes in the eastern tropical Pacific, partial support from this project through F. Galván's budget.

Gladis López-Ibarra. Ph.D. Candidate, Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, La Paz, B.C.S, Mexico. Working on stable isotopes in zooplankton collected by this project, with partial support for isotope analyses provided by this project.

Vanessa Alatorre-Ramírez. MS. Candidate, Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, La Paz, B.C.S, Mexico. Working with diet data of fishes in the eastern tropical Pacific, partial support from this project through F. Galván's budget.

10. Personnel:

(i) Number of employees by job title and terminal degree that received more than 50% support from NOAA, including visiting scientists:
(ii) Number of employees/students that received 100% of their funding from an OAR laboratory and/or are located within that laboratory:
(iii) Number of employees/students that were hired by NOAA during the past year: Secretariat of the Pacific Community: Caroline Sanchez – Lab assistant (4 months during FY06), Kim Loeun – Lab assistant (2 months during FY06)

11. Images and Captions: Images to be provided upon request.

12. For multi-year projects, provide budget for the next year on a separate page.

The project has requested and will be receiving a fourth increment of funding to complete tuna stomach content analysis.