

JIMAR – PFRP ANNUAL REPORT FOR FY 2005

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

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

Recent 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. The 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 2005:

2.1 Sampling:

In the western and central Pacific, 29 sampling trips on tuna fishing vessels have been completed. Of the 2513 stomachs collected so far from 60 species, 1605 have been examined in the laboratory. The diet data for albacore, yellowfin, and bigeye tuna have been partially analyzed. Zooplankton samples were collected during a scientific cruise in the western Pacific. In the central Pacific, an area that was previously underrepresented in our collection efforts, 550 tissues samples from 18 pelagic organisms were collected

during 2 recent NOAA oceanographic cruises. During the second cruise, a TAO/Triton-buoy cruise, water samples were also collected along a N-S transect across the equator, which will enable us to couple physical and chemical oceanographic conditions to the isotope ecology of tunas. In the eastern Pacific, 31 sampling trips on tuna purse-seine vessels were completed during this annual report period. Samples of stomachs and tissues have been collected from more than 8800 specimens of about 41 taxa. The majority of the stomach samples have been partially or completely analyzed in the laboratory, and the diet data for about 30 predator species caught in 41 purse-seine sets have been analyzed by a student at CICIMAR, Mexico. Ten zooplankton samples and 17 POM samples were collected on a NOAA shark research cruise in the eastern Pacific.

In the cold tongue-warm pool pelagic ecosystem, we have documented that different regions have different isotope compositions. However, very little in the ocean is stationary enough or has a suitable lifespan to incorporate a permanent regional isotopic signal at the base of the food chain. To overcome these spatial and temporal hurdles, we predict that long-term isotopic values will be captured in the tissues of barnacles living on the stationary TAO-buoys. We recently collected barnacles from 10 different buoys in the central Pacific and have established collaborations with NOAA scientists to continue collecting barnacles from other TAO buoys. Once we have determined the regional isotope compositions of these primary consumers, we can better track movement patterns of mobile pelagic fishes.

2.2 Stable isotope and mercury analyses

We analyzed samples for stable isotope analysis of (1) eastern Pacific yellowfin tuna, bigeye tuna, flyingfishes, and myctophid fishes, (2) western Pacific pelagic fish tissue samples, (3) tunas from throughout the equatorial Pacific to incorporate into our isotope biogeographic maps. (1) One-hundred and eighty-nine samples (composites of several individuals) from the eastern Pacific have been analyzed. The nitrogen isotope ratios of the yellowfin, skipjack, bigeye, myctophids, and flyingfishes were incorporated into regional isotope biogeographic maps. (2) Three-hundred and twenty samples from the western Pacific have been analyzed. Focusing on just yellowfin tuna, the isotope values indicated that the fish have different diets in different areas. Samples from Micronesia in the warm pool are much different than samples from New Caledonia and French Polynesia, south and east of the warm pool, respectively. (3) After considerable effort to analyze samples from throughout the equatorial Pacific, we have developed our first basin-wide isotope biogeography maps. These maps are more robust for the eastern Pacific, where the geographical coverage of the samples is of high resolution. The maps demonstrate that the isotope values of the tunas are not homogenous, which would be expected if they moved and mixed extensively. Our maps illustrate strong patterns, both basin-wide (between the western and eastern Pacific) and regionally (within the eastern Pacific), suggesting little movement.

Seventy-one samples were analyzed for methyl mercury concentrations. The results for the tunas indicated that methyl mercury concentrations increase with fish size. Our complete data set, which includes skipjack, wahoo, mahi mahi, oilfish, prey species, and others, indicates that methyl mercury contents increased with depth of foraging. Accordingly, we intend to couple the Hg and isotope data sets to examine foraging depth by pelagic fishes.

2.3 Modeling and diet analyses:

Progress has been made to develop a new ecosystem model, based on Ecopath with Ecosim (EwE), for the western Pacific. Efforts were focused on obtaining better diet data for the model. Instead of taxonomic prey components, we are considering classifying the main prey according to their depth distribution and vertical migratory behaviour. Hence, the prey found in the stomach contents have been classified into 6 categories (epipelagic, non-migrant mesopelagic, surface migrant mesopelagic, non-migrant bathypelagic, surface migrant bathypelagic, and intermediate migrant bathypelagic). The diets of the main predators are now examined according to these classes, and we are in the process of gathering the data to formulate a new Ecopath model. 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 comparative study has been carried out using diet data for yellowfin tuna in the eastern and western Pacific. This preliminary study shows important differences between the food habits in the two regions, probably linked to the depth of the thermocline, to the depth of the oxygen-minimum zone in the eastern Pacific, and to the presence of numerous coral islands in the western Pacific. A detailed analysis of the data for the western Pacific highlights differences in the diets among yellowfin from New Caledonia (epi- and meso-pelagic fishes), Polynesia (epipelagic fishes and crustaceans, juvenile reef fishes), and PNG-Solomon (epipelagic fishes and crustaceans, juvenile reef fishes). Differences are also observed in the isotope data, but more samples need to be analyzed to link the diet data and the isotope data of the tunas.

3. Plans for the next fiscal year:

This 3-year project is finishing at the end of 2005. Sampling in all regions of the equatorial Pacific will continue during the remainder of the project to increase the numbers of predator stomachs, muscle, and liver samples collected. More samples from all three regions will be analyzed isotopically to fill-in the gaps of the isotope-biogeography maps for the most important species, and to address other scientific questions that we have developed. Sampling efforts throughout the project have been very successful, and the samples remaining to be analyzed will be chosen carefully to provide the most information possible with the remaining funds. More opportunistic sampling on research vessels will be undertaken. A marine mammal survey cruise on a NOAA vessel will transit the eastern Pacific this summer, and spend 120 sea days in the triangle between Hawaii, Palmyra, and Johnston Atoll. Samples of POM, zooplankton, forage species, and predator fishes will be collected for our project by NOAA scientists. In the western/central Pacific, the focus will be on stomach examination and data analysis. A comparison of trophic structure of the western and eastern Pacific will be continued for the major predator species. A new EwE model for the western Pacific will be formulated with the diet matrix based on prey groups classified according to their vertical distribution and behavior. Stomach contents analysis of the predators caught by purse-seine in the eastern Pacific will be continued by CICIMAR personnel. The PIs and collaborators of this project plan to meet before the end of the year to draft a final report and to work on publications.

4. Papers published in refereed journals during FY 2005:

None.

4.1. Papers in preparation for refereed journals:

Graham, B., D. Grubbs, K. Holland, B. Popp. In preparation. Rapid ontogenic dietary shift in juvenile yellowfin tuna.

Graham, B., B. Popp, K. Holland, and B. Fry. In preparation. Tissue turnover rates measured in captive and wild yellowfin tuna, *Thunnus albacares*: implications for using chemical tags in migration studies.

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

5.1. Other papers:

Olson R., J. Young, V. Allain and F. Galván-Magaña. 2005. OFCCP workshop on the application of stable isotopes in pelagic ecosystems, La Paz, B.C.S., Mexico, 31 May–1 June 2004. GLOBEC Newsletter 11(1): 42-44.

Allain, V. 2004. Ecopath model of the pelagic ecosystem of the WCPO and related projects. INF-ECO-1. SCTB17 Information Paper. Majuro, Marshall Islands. 9-18 August 2004. 11 pp.

Allain, V. 2004. Diet of yellowfin tuna in different areas of the western and central Pacific Ocean. BIO-1. SCTB17 Working Paper. Majuro, Marshall Islands. 9-18 August 2004. 20 pp.

5.2. Technical reports:

Olson R., J. Young, V. Allain and F. Galván-Magaña. 2005. CLIOTOP Working Group 3 meeting report: La Paz, B.C.S., Mexico, 31 May–1 June 2004. GLOBEC-CLIOTOP Regional Programme, 8 pp.

Olson R., J. Young, V. Allain and F. Galván-Magaña. 2005. GLOBEC-OFCCP workshop on the application of stable isotopes in pelagic ecosystems La Paz, B.C.S., Mexico, 31 May–1 June 2004. GLOBEC-OFCCP Multinational Programme, 8 pp.

5.3. Meeting presentations:

Allain, V., B. Graham, R. Olson, B. Popp, F. Galvan-Magana, and B. Fry. Stable isotopes as tracers of trophic structure and tuna movement in the equatorial Pacific pelagic ecosystem. Poster. Fourth International Conference on Applications of Stable Isotope Techniques to Ecological Studies. Wellington. April 19-23 2004.

Graham, B., K. Holland, D. Grubbs, B. Popp, and B. Fry. Tuna trophic dynamics in Hawaiian waters: Are there differences in the $\delta^{15}\text{N}$ of mesopelagic and epipelagic food webs? Poster. Fourth International Conference on Applications of Stable Isotope Techniques to Ecological Studies. Wellington. April 19-23 2004.

Allain, V., B. Graham, R. Olson, B. Popp, F. Galvan-Magana, and B. Fry. Trophic structure and tuna movement in the warm pool–cold tongue pelagic ecosystem of the equatorial Pacific. 55th Tuna Conference. Lake Arrowhead, California. 24-27 May 2004.

Graham, B., K. Holland, D. Grubbs, B. Popp, B. Fry, V. Allain, R. Olson, F. Galvan, and D. Itano, Natural and experimental diet shifts in yellowfin tuna as tracked by stable isotope analysis. 55th Tuna Conference. Lake Arrowhead, California. 24-27 May 2004.

Ménard, F., V. Allain, F.X. Bard, B. Fry, B. Graham, F. Marsac, R. Olson, B. Popp, M. Potier, R. Sabatie. Stable isotope as tracers of trophic structure in open-sea ecosystems. Poster. 55th Tuna Conference. Lake Arrowhead, California. 24-27 May 2004.

Allain, V., B. Graham, R. Olson, B. Popp, F. Galvan-Magana, and B. Fry. Trophic structure and tuna movement in the warm pool – cold tongue pelagic ecosystem of the equatorial Pacific. GLOBEC OFCCP and CLIOTOP Workshop on the Application of Stable Isotopes in Pelagic Ecosystems, La Paz, B.C.S., Mexico, 31 May–1 June 2004.

López-Ibarra, G. Trophic structure of the pelagic copepods in the eastern tropical Pacific Ocean. GLOBEC OFCCP and CLIOTOP Workshop on the Application of Stable Isotopes in Pelagic Ecosystems, La Paz, B.C.S., Mexico, 31 May–1 June 2004.

Allain, V. Regional differences in stable C and N isotopes in predator and prey taxa in the equatorial Pacific: recent results. GLOBEC OFCCP and CLIOTOP Workshop on the Application of Stable Isotopes in Pelagic Ecosystems, La Paz, B.C.S., Mexico, 31 May–1 June 2004.

Olson, R. Sample-size considerations. GLOBEC OFCCP and CLIOTOP Workshop on the Application of Stable Isotopes in Pelagic Ecosystems, La Paz, B.C.S., Mexico, 31 May–1 June 2004.

Graham, B., B. Fry. Lipid effects on stable isotope analyses. GLOBEC OFCCP and CLIOTOP Workshop on the Application of Stable Isotopes in Pelagic Ecosystems, La Paz, B.C.S., Mexico, 31 May–1 June 2004.

Allain, V. Diet of yellowfin tuna in different areas of the western and central Pacific Ocean. 17th Meeting of the Standing Committee on Tuna and Billfish. Majuro, Marshall Islands. 9-18 August 2004.

Allain, V., B. Graham, R. Olson, B. Popp, F. Galvan-Magana, and B. Fry. 2004. Diet of the yellowfin tuna in the Pacific Ocean. PFRP PI Workshop. Hawaii. 29 November - 1 December 2004.

Olson, R., B. Graham, V. Allain, F. Galván-Magaña, B. Popp, and B. Fry. Key pelagic prey and their tuna predators: Isotope ecology in the eastern tropical Pacific Ocean. PFRP PI Workshop. Hawaii. 29 November - 1 December 2004.

6. Graduates:

No students have graduated.

7. Awards:

B. Graham received the SOEST's Lenoida fisheries scholarship.

8. Publication Count:

	JL Lead Author			NOAA Lead Author			Other Lead Author		
	FY03	FY04	FY05	FY03	FY04	FY05	FY03	FY04	FY05
Peer-reviewed									
Non-peer reviewed							2	2	3

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 3rd 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.

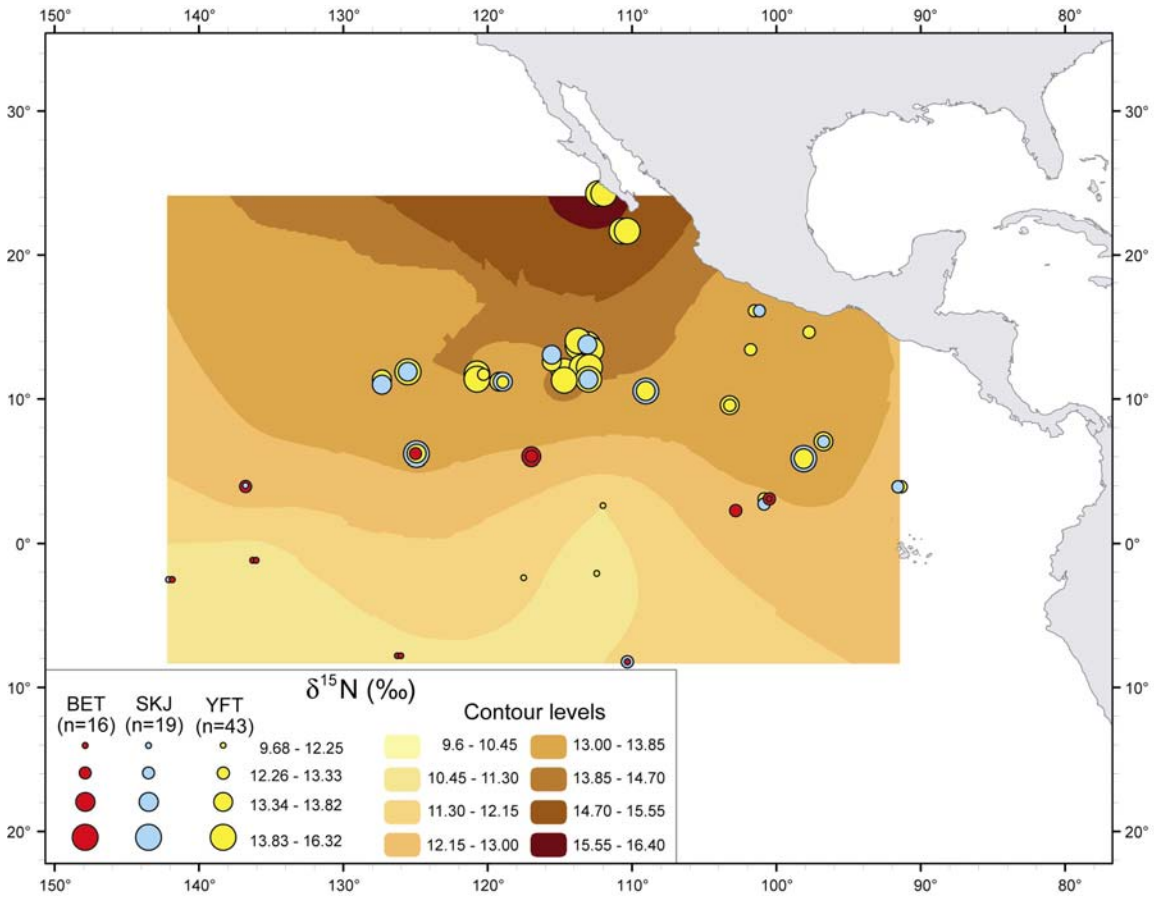
Vanessa Alatorre-Ramírez. MS. Candidate, Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, La Paz, B.C.S, Mexico. Working with diet data of fishes in the eastern tropical Pacific, partial support from this project through F. Galván’s budget.

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:

University of Hawaii: Brian Popp (1 month/year), Terri Rust (2 month per year), Brittany Graham (GA, 3 mo/yr summer salary), Undergraduate Student (10 h/week @ \$10/h)

11. Images and Captions:



● Caption 1: Nitrogen stable isotope ratios, $\delta^{15}\text{N}$ (‰), in the white muscle of yellowfin, skipjack, and bigeye tunas caught in the eastern Pacific Ocean. A significant trend of higher $\delta^{15}\text{N}$ values at higher latitudes is apparent.

Study Citation	Tissues Analyzed	$\delta^{15}\text{N}/\text{day}$	Half-life (days)
Teizen et al. 1984	Gerbil		
	Liver	0.11	6.4
	Muscle	0.025	27.7
Hobson and Clarke 1992	Quail		
	Liver	0.27	2.6
	Muscle	0.056	12.3
Hesslein et al. 1993	Coldwater Fish		
	Liver	0.0025	277
	Muscle	0.0018	385
Current PFRP Study	Yellowfin Tuna		
	Liver	0.018	16.1
	Muscle	0.043	39.6

- Caption 2: Tissue turnover rates calculated from different organisms, including those calculated from this research project on captive yellowfin tuna. The data demonstrate that yellowfin tuna tissue turnover rates are comparable to those of mammals.