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A REVIEW OF COOPERATIVE RESEARCH AT THE NMFS GALVESTON LABORATORY CONDUCTED UNDER THE MEXUS-GULF PROGRAM

Una Revisión de Investigación Cooperativa del Laboratorio NMFS Galveston Conducido Bajo el Programa Mexus-Gulf

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ABSTRACT

Fisheries research and management agencies in the United States and Mexico have established a unique partnership devoted to research and management of common fisheries issues in the Gulf of Mexico. This partnership, known as the Mexus-Gulf Program, has been in existence since 1977. Mexus-Gulf has led to numerous important contributions, highlighted in this document, with respect to protection of living marine resources and fishery management in the Gulf of Mexico. The Galveston Laboratory of the National Marine Fisheries (Southeast Fisheries Science Center) is involved with the Mexus-Gulf program through cooperative research with Mexican scientists, focusing on penaeid shrimp stocks and endangered sea turtles in the Gulf of Mexico. This document highlights the cooperative research conducted at the Galveston Laboratory under the auspices of the Mexus-Gulf program.

Key word: Mexus-Gulf, Penaeid shrimp, sea turtles, research, Gulf of Mexico.

RESUMEN

Agencias de investigación y manejo de pesquerías en los Estados Unidos y México han establecido una asociación dedicada únicamente a la investigación de pesquerías comunes en el Golfo de México. Esta asociación conocida como "Mexus-Golfo", ha existido desde 1977. Mexus-Golfo pionero en numerosas contribuciones importantes, resaltadas en este documento, con respecto a los recursos vivos marinos y manejo de las pesquerías en el Golfo de México. El Laboratorio Galveston de la National Marine Fisheries (Southeast Fisheries Science Center) esta involucrado con el programa Mexus-Golfo a través de investigación cooperativa con científicos mexicanos, se enfocan en la evaluación del camarones peneidos y de las especies de tortugas marinas en peligro de extinción del Golfo de México. Este documento subraya la investigación cooperativa llevada a cabo por el Laboratorio Galveston bajo el patrocinio del programa Mexus-Golfo.

Palabras clave: Mexus-Golfo, camarones peneidos, tortuga Lora, investigaciones, Golfo de México.

Introduction

Since its inception in 1977, the Mexus-Gulf program has served as an important instrument in the research and conservation of fishery resources and endangered species throughout the Gulf of Mexico. Mexus-Gulf is an international agreement (Memorandum of Understanding) between the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC) and its counterpart in Mexico, the Instituto Nacional de La Pesca (INP). The focus of the program is to provide a mechanism to promote cooperative fishery research and technology projects of mutual interest in the Gulf of Mexico and Caribbean. The agreement allows fishery scientists and managers from both countries to collaborate on

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specific issues, with respect to fishery resources, that exist throughout the Gulf of Mexico regardless of political jurisdictions or international boundaries.

Mexus-Gulf had its genesis in the plan to phase out U.S. shrimp fishing in Mexican waters, which terminated in December 1979, under the November 1976 Bilateral Fisheries Agreement between the United States and Mexico. Incorporated in that agreement was a statement requiring that a bilateral scientific committee be established to maintain active fishery research in the Gulf of Mexico and to keep lines of communication open. At the request of either government, a bilateral panel could be established to deal with areas of fishery research of mutual interest. Initially, the Mexus-Gulf program focused on evaluating the migration of commercial shrimp stocks across the U.S.-Mexico border.

The Mexus-Gulf program is comprised of a number of working groups that focus on research involving specific stocks or fishery issues. These working groups include:

Shrimp	Remote Sensing
Sea Turtles	Seafood Technology
Sharks	Fishing Gear Technology
Pelagics	Ichthyoplankton and Hydrography
Ecosystem/Ecopath™*	

All of these programs have not been existing over the entire 21-year period. The most active MEXUS-Gulf projects have concerned turtles, shrimp, ichthyoplankton, king mackerel, recreational fishing, and remote sensing gear technology. The importance of the working groups for specific stocks is evident; shrimp, shark, and pelagic fish species are commercially important resources for both the United States and Mexico. The sea turtle working group facilitates protection and recovery of threatened and endangered marine turtles. The remote sensing and technology working groups allow for an exchange of information on applications of satellite imagery, development of new techniques for fishing, and for processing of seafood in a safe and more efficient manner. The ichthyoplankton and hydrography working group focuses on oceanic sampling, adding knowledge about planktons and planktonic life stages of fishery stocks, as well as the environmental factors which contribute to their survival. The Ecosystem/Ecopath™ working group was established to promote the use of ecosystem principles in management of fishery resources and the habitats in which they occur; this working group was added to the Mexus-Gulf program in 1996 at the request of scientists at the INP.

Scientists involved with Mexus-Gulf working groups convene annually, with the location usually alternating between sites in the U.S. and Mexico. Individual meetings include presentations of past and ongoing research efforts, followed by working group sessions. In each working group session, research interests, problems, issues, and information requirements are discussed. Additionally, new plans are formulated for cooperative research in the upcoming year for each working. The following review summarizes the work conducted by scientists at INP and the NMFS Galveston Laboratory, under the auspices of the shrimp, sea turtle, and ecosystem working groups.

*** The use of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA, or the Department of Commerce.**

Historical research

Shrimp Working Group

Fishery Landings and Management

Mexus-Gulf has provided scientists with a means of exchanging information, data, publications, assess models, and many other items relative to management of shrimp stocks occurring in the Gulf of Mexico. The most common exchange of information includes annual statistics on the penaeid shrimp fisheries, including catch and landing statistics, recruitment rates, fishing effort, etc. On several occasions, scientists have collaborated on analyses of population dynamics and shrimp stock trends, exchanging additional data on predator-prey interactions, habitat considerations, stock-recruitment relationships, overfishing definitions, growth and life history parameters, and management mechanisms that regulate commercial landings.

In the U.S. controlled waters of the Gulf of Mexico off Texas, there exists an annual Federal/State cooperative seasonal closure (May-July) for the offshore brown shrimp (*Penaeus aztecus*) fishery (Jones *et al.*, 1982; Klima *et al.*, 1982; Nichols, 1982). The basis for the closure is to allow adequate passage of subadult shrimp from estuaries to offshore waters. Estuaries along the Texas coast are primary nurseries for penaeid shrimp, but most of these bay systems are connected to the Gulf via relatively few passes or channels. Without the closure, it would be easier for the fishing industry to capture large quantities of small shrimp emigrating from the estuaries. The Texas Closure, as it is commonly known, allows emigrating shrimp to grow to a larger and more valuable size. The closure represents a unique relationship among state and federal management agencies. The State of Texas enacted a law in 1959 (Klima *et al.*, 1982), establishing the closure from the beachfront to the edge of the territorial sea (9 nautical miles) which usually begins on May 15th of each year. The closure is set for a minimum of 45 days and a maximum of 60 days. Texas Parks and Wildlife Department (TPWD) is responsible for determining the date of opening, based on population size and maturity estimated from samples taken in the estuaries and nearshore waters. Since 1981, NMFS regulations provide for concurrent closure of federally controlled waters, from the territorial seas out to the limit of the U.S. exclusive economic zone (200 nm). The federal closure allows for the TPWD to set the annual dates that initiate, and end the closure. State and federal enforcement authorities, including the U.S. Coast Guard and the NMFS maintain enforcement of the closure. In recent years, the scientific data that support the closure have been of particular interest to scientists and managers of Gulf shrimp fisheries in Mexico since they established a closure (veda) in the brown shrimp fishery off of Tampico. In 1996, a workshop of scientists, managers, and industry representatives of the two countries was convened in an attempt to establish a concurrent closure of shrimping grounds in the western Gulf of Mexico. The basis for the concurrent closure was, 1) to reduce possible impacts of poaching by shrimpers along the U.S.-Mexico boundary, 2) to promote economic stability in the fishery through simultaneous marketing of various sized shrimp, and, 3) to establish similar management conditions for the common shrimp fishery in both countries. Closures dates for each area however, are based on biological considerations for individual stocks of *P. aztecus*. Unfortunately, the limits of the closure in Texas are established by mandate of the Texas Legislature, and a mutual agreement for a simultaneous opening could not be realized. There remains some optimism that simultaneous closures may be established at a future time.

Mark-Recapture Studies

During 1978-1980, scientists collaborated on a major mark-recapture study to evaluate trans-boundary migratory patterns of penaeid shrimp in the western Gulf of Mexico. Brown shrimp and pink shrimp (*P. duorarum*) were tagged at several inshore and offshore sites along the coast of Texas and Tamaulipas. Shrimp were captured with trawls and tagged with polyethylene streamer tags and released (Sheridan *et al.*, 1987). Monthly lotteries, awarding up to $500 U.S., were provided to fishermen as an incentive for reporting locations and dates of recaptured shrimp (Cody and Fuls, 1981). Recaptures submitted with incomplete return data (i.e., species type or location of recapture omitted) were not included in analyses (Sheridan *et al.*, 1987).

Directional movement was evaluated by number of recaptures per 10^3 ton of commercial landings (R/L values; Sheridan *et al.*, 1987) and by vector analysis of recaptures (Cody and Avent, 1980; Cody and Fuls, 1981). Vector analysis assumes straight line migration and uniform landing patterns, thus it is a good secondary indicator of migration and it reflects short-range movements (Sheridan *et al.*, 1987). Longshore movement of shrimp to the "north" reflected migration of shrimp toward the Mississippi River; movement "south" indicated longshore migration of shrimp towards the Mexican port of Veracruz. Recaptures to the east or west of tagging sites generally indicated offshore or onshore migration patterns, respectively.

A total of 121,563 shrimp were tagged and released in estuaries and an additional 90,670 were marked and released in offshore waters (Tables 1-3). Overall, 12,597 shrimp were recaptured (Table 4), accounting for nearly 6% of all shrimp tagged and released; less than 1% of shrimp released in estuaries were recaptured. The low number of recoveries was attributed to handling stress, high water temperature or predation (Cody and Avent, 1980). In some cases, hook-and-line capture of migratory fish (i.e., mackerels) following the release vessels were observed to have high numbers of tagged shrimp in their mouths and stomachs (Gregg Gitschlag, NMFS-Galveston, personal communication).

Information gathered from recaptures indicated a net population movement of *P. aztecus* to the south (towards Veracruz) along the Texas-Tamaulipas coast (Sheridan *et al.*, 1987; Figures 1-2). However, migration was variable, with some tagged shrimp moving northward; general southerly movements were observed during spring and fall, while northerly movements were noted in late spring and summer.

Most (almost 70%) of the brown shrimp recaptured were caught within 30 days of their release (Sheridan, 1987). Pink shrimp exhibited a more variable distribution and no overall movement pattern (Sheridan *et al.*, 1987; Tables 1, 3). About half of pink shrimp recaptured were caught within 30 days of release (Sheridan *et al.*, 1987).

Only 268 (108 *P. aztecus*, 160 *P. duorarum*) of all recaptured shrimp had traversed the Texas-Mexico border (Klima *et al.*, 1987). Maximum distances traveled were 620 km for brown shrimp and 428 km for pink shrimp (Sheridan *et al.*, 1987).

A later mark-recapture study on the Campeche fishing grounds in spring of 1981 indicated that pink shrimp generally exhibited a north-northeast movement but migration existed in both north and south directions, thus definitive results were not observed (Klima *et al.*, 1987).

The most recent cooperative shrimp tagging study was conducted in the offshore waters along the coasts of Texas and Tamaulipas during the summer of 1986 (Sheridan *et al.*, 1989). Vector analysis, analysis of variance (ANOVA), and by recaptures per unit of fishing effort (R/f) were used to analyze the data. A total of 42,223 shrimp were marked and released (59.2% *P. aztecus*, 40.8% *P. duorarum*). Of those, 13.4% (5,639) were recaptured; 112 shrimp released off Tamaulipas (50 *P. aztecus*, 62 *P. duorarum*) were recaptured off of Texas but only 5 brown shrimp and 2 pink shrimp released in Texas waters were recaptured in the Tamaulipas fishery. Although analyses for comparison differed from the previous study, the results indicated no preferred movement for brown shrimp and only pink shrimp released off Tamaulipas exhibited significant movement in a northward direction (Sheridan *et al.*, 1989). Differences in reported migration patterns (compared to earlier studies) were attributed to differences in data collection and analytical techniques used in the studies. Fishing effort patterns along the U.S.-Mexico Gulf coast were identified as the primary factor influencing recapture of marked shrimp (Sheridan *et al.*, 1989).

Fishery Forecasts

NMFS scientists have long since utilized a number of models to forecast annual landings of brown shrimp catch in the northern Gulf (Baxter, 1963; Baxter and Sullivan, 1986; Matthews, 1992; Walker and Saila, 1986) and pink shrimp catch in the Tortugas area off

Table 1. Directional movements of tagged brown shrimp (*Penaeus aztecus*) and pink shrimp (*Penaeus duorarum*) released in Texas and Tamaulipas estuaries as determined by vector analysis of offshore recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subareas (SS) of release. N = number of offshore recaptures, * = significant difference in expected 1:1 north-south ratios as calculated by chi-square analysis (P<0.05). From Sheridan *et al.*, 1987.

Releases					Vector Analysis[1]			Recaptures per 10^3 t			
ear	SS	Months	Number	Total Recaptures	N	North	South	N	North	Within	South
						Brown Shrimp					
1978	20	May-July	42,180	7	0			0			
1979	20	June-July	9,598	0	0			0			
	21	April-June	15,776	84	18	2	4	18	0.0	11.6	42.2
	23	April-May	10,083	31	2	1	1	2	0.0	1.9	2.8
1980	18	June-July	11,350	1	0			0			
	19	May, July	10,218	10	0			0			
	21	March-April	2,912	229	11	4	7	11	0.0	1.6	48.0
	23	March-June	4,362	31	5	1	4	5	8.4	9.0	0.0
otal			106,479	393	36			36			
						Pink Shrimp					
1979	21	April-June	2,778	123	35	12	6	35	0.5	11.1	27.4
	23	April-May	384	2	0						
1980	21	March-April	9,548	1,296	82	23	59*	82	0.5	13.8	21.9
	23	March-June	2,374	13	2	1	1	2	18.9	4.8	0
Total			15,084	1,434	119			119			

North- (North + South) = number of onshore/offshore recaptures.

Table 2. Directional movements of tagged brown (*Penaeus aztecus*) shrimp released off Texas and Tamaulipas as determined by vector analysis of recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subareas (SS) of release. N = number of offshore recaptures, * = significant difference in expected 1:1 north-south ratios as calculated by chi-square analysis (P<0.05). From Sheridan *et al.*, 1987.

Releases					Vector Analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number	Total Recaptures	N	North	South	N	North	Within	South
1978	20	August	2,832	193	73	45*	24	171	4.0	63.6	2.4
		October	1,430	153	101	30	64*	127	1.5	41.7	4.6
	22	September	2,011	336	264	42	222*	264	0.3	242.7	65.8
	23	September	5,859	1,416	1,205	297	889*	1250	10.9	388.2	421.8
	24	September	539	62	46	20	26	61	10.6	171.1	27.6
	25	September	503	64	59	21	36	62	10.4	265.8	58.6
1979	18	September	771	120	66	5	57*	86	0.5	105.0	18.5
	19	September	1,760	158	89	19	65*	121	3.3	114.1	6.7
		October	8,270	1,039	796	53	607*	811	13.4	155.3	4.4
		November	2,569	109	80	44	30	95	25.9	74.4	3.4
	20	May	978	139	95	21	47*	115	0.0	18.5	35.0
		September	349	37	30	18	11	33	6.7	16.3	8.7
		October	1,106	225	156	28	104*	196	3.0	50.3	10.6
	21	May	1,620	444	141	59	78	191	3.7	51.4	3.9
	22	May	519	132	92	25	46*	98	3.2	445.5	14.2
		June	1,509	183	112	8	90*	167	0.5	573.0	70.0
		September	168	12	10	1	9*	10	0.0	110.6	23.1
	23	May	549	121	86	34	52	86	175.8	75.1	17.9
		June	1,224	193	110	36	66*	176	239.9	243.3	69.1
	24	June	2618	459	357	235*	118	423	34.2	768.3	16.1
1980	19	June	11677	882	437	177	241*	653	16.4	156.5	7.4
		July	10545	873	336	34	277*	598	5.0	98.0	28.3
	20	June	2013	67	47	12	20	52	2.8	12.8	2.4
		July	4362	229	163	7	150*	220	0.3	30.4	40.4
	21	May	423	113	83	28	46*	101	2.4	34.3	15.1
		June	298	15	14	6	6	14	0.7	2.6	8.5
	22	May	883	106	100	44	40	105	4.5	214.4	11.9
	23	May	974	129	93	37	53	121	152.5	73.5	25.0
	24	May	1062	152	71	35	28	143	25.6	328.6	33.4
	25	May	2064	666	536	367*	169	641	105.2	779.6	0.0
Total			71,485	8,827	5,848			7,191			

[1] North- (North + South) = number of onshore/offshore recaptures

of southern Florida (Sheridan, 1996). Landings of pink shrimp from the Tortugas off Florida and the Campeche shrimp grounds off Mexico both declined in the late 1980's through the mid 1990's, but recently appear to have rebounded to previous population levels (Sheridan, 1996). Seasonal or permanent closures have both been used to increase production and value of the fisheries. To help forecast shrimp abundance, a predictive model was developed for the Tortugas fishery (Sheridan, 1996) to provide information for resource managers. The model also helps scientists to understand the interaction of environmental parameters (rainfall, freshwater inflow, tidal level, air temperature, wind speed, and wind direction) on the productivity of shrimp nursery areas. A similar model forecast model has been developed for the brown shrimp fishery off of Texas (Matthews, 1992). This environmental model supplements predictions of another forecast based on capture of subadult shrimp in the inshore fisheries of Galveston Bay, Texas (Baxter and Sullivan, 1986). Although recruitment processes remain a topic of detailed investigation, these forecast models, using environmental parameters as driving variables, have provided accurate predictions of landings. Scientists from the shrimp working group collaborated recently in an attempt to develop a similar forecast model for the Campeche pink shrimp fishery.

Table 3. Directional movements of tagged pink shrimp (*Penaeus duorarum*) released off Texas and Tamaulipas as determined by vector analysis of recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subareas (SS) of release. N = number of offshore recaptures, * = significant difference in expected 1:1 north-south ratios as calculated by chi-square analysis (P<0.05). From Sheridan *et al.*, 1987.

Releases					Vector Analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number	Total Recaptures	N	North	South	N	North	Within	South
1978	20	October	68	7	5	2	3	6	0.9	3.9	1.6
	22	September	23	4	3	2	1	3	1.2	5.6	1.6
	23	September	24	5	5	0	5	5	0.0	0.0	77.4
	24	September	65	9	6	2	4	8	3.6	12.1	5.7
	25	September	77	12	9	2	7	10	6.6	45.2	0.0
1979	18	September	4	1	1	1	0	1	0.0	6.0	0.0
	19	September	86	3	2	1	1	2	6.0	0.0	1.8
	20	May	361	49	31	7	20*	39	0.0	6.3	9.4
		September	34	1	1	0	1	1	0.0	2.1	0.0
		October	17	1	0	0	0	0	0.0	0.0	0.0
	21	May	8,463	1,793	1,068	454	585*	1,688	16.4	359.1	26.1
	22	May	846	195	164	54	75	182	2.8	382.7	10.8
		June	68	6	2	0	2	5	0.0	23.3	4.3
		September	26	0	0	0	0	0	0.0	0.0	0.0
	23	May	819	120	111	47	64	111	169.6	64.2	6.6
		June	367	32	16	1	13*	17	0.0	13.6	22.9
	24	June	421	77	68	34	34	73	19.5	133.0	16.1
1980	20	June	235	17	12	6	4	14	5.5	9.9	2.1
		July	15	4	4	1	3	4	0.3	0.0	1.0
	21	May	2885	812	549	399*	138	778	13.7	207.2	11.8
		June	386	93	68	39*	17	87	7.2	38.7	0.0
	22	May	1035	102	95	53	36	99	6.0	178.0	6.4
	23	May	1203	202	125	53	68	189	14.3	139.6	17.0
	24	May	1134	166	70	38*	21	163	17.7	317.2	22.3
	25	May	523	59	47	36*	11	58	16.4	54.0	4.7
Total			19,185	3,770	2,462			3,543			

[1] North- (North + South) = number of onshore/offshore recaptures.

Table 4. Total number of recaptures and number and percentage of transborder recaptures (in parentheses) from all brown shrimp and pink shrimp releases by statistical subareas of release.

Release Subarea	Brown Shrimp Recaptures		Pink Shrimp Recaptures	
	Total	Transborder	Total	Total Transborder
18	120	0 (0.0)	1	0 (0.0)
19	3,060	5 (0.2)	3	0 (0.0)
20	1,043	10 (1.0)	79	1 (1.3)
21	572	12 (2.1)	2,698	82 (3.0)
22	769	46 (6.0)	307	72 (23.5)
23	1,859	2 (0.1)	359	2 (0.6)
24	673	1 (0.1)	252	0 (0.0)
25	730	0 (0.0)	72	0 (0.0)

Table 5. Kemp's ridley sea turtles nesting at Padre Island National Seashore, Texas. Eggs and hatchlings of headstarted turtles provided obtained from the Rancho Nuevo nesting beach through cooperation with INP under the Mexus-Gulf program. Headstarted turtles were imprinted at the Padre Island National Seashore prior to captive rearing at the NMFS Galveston Laboratory. Data from Donna Shaver (July 1998, USGS, personal communication).

Year	Kemp's Ridley Nests Observed	Confirmed Headstart Turtles
1995	2	0
1996	5	2
1997	5	0
1998[a]	9	3[b]

[a] observed Kemp's Ridley nests through July 1998.
[b] only 2 of the 3 nests were within the boundaries of Padre Island National Park.

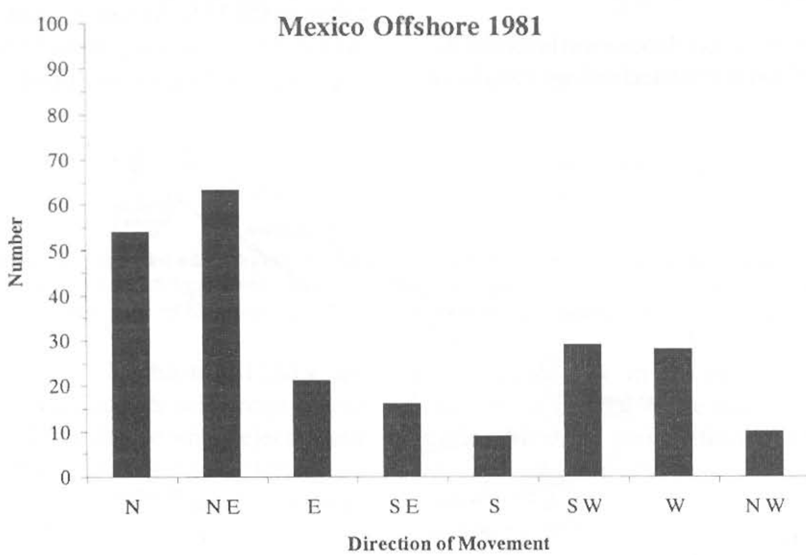

Figure 1. Distribution of pink shrimp on the Campeche Bank by direction of movement. From Klima *et al.*, 1987.

Correlation and stepwise regression analyses were utilized to evaluate the degree of correlation of offshore fishery landings with biotic and abiotic parameters and/or nearshore fishery landings in the Campeche area. These parameters included air and water temperature, rainfall, freshwater inflow levels, mean tidal height, salinity, and catch of juveniles in small shrimp by month. The biological year (between recruitment peaks) for pink shrimp taken in the Campeche fishery begins in September and ends in August. Juveniles utilize coastal seagrass beds as nurseries during August and September, during which time they are vulnerable to capture from the nearshore fishery.

In the statistical analyses, annual landings, grouped by biological year, were used as the dependent variable. The independent variables were arbitrarily tested for individual months (July–December), and mean values for groups of months (Jul.-Oct.; Aug.-Sep.; Aug.-Oct.; Sep.-Oct.; Oct.-Dec), based on the advice of the fishery scientists from Mexico (Abraham Navarrete del Próo, INP, personal communication). The goal of the analysis was to find the variables, or combination of variables, that best explained the variability in the offshore landings, using maximum R^2 as the primary statistic for assessing forecast suitability.

Results from the correlation analysis indicated that variability in offshore landings was best explained by catch of subadult shrimp in September ($R^2 = 0.56$), and with water temperature for the same month ($R^2 = 0.42$). A combination of those two independent variables in the stepwise regression resulted in a significant correlation with offshore landings (adjusted $R^2 = 0.829$; $p = 0.0004$). No significant correlation of offshore pink shrimp catch with other variables (air temperature, rainfall, salinity, mean tide level) was observed. Consequently, the best model for the Campeche pink shrimp fishery emulates those developed for predicting Texas and Louisiana brown shrimp landings (Baxter and Sullivan, 1986; Matthews, 1992), but not the model used for Florida pink shrimp which used rainfall and freshwater inflow as the primary driving variables (Sheridan, 1996). However, the lack of data (15 years, various months missing) decreased the power of the statistical analyses and further evaluation is required to evaluate the suitability of this model to predict Campeche pink shrimp landings.

Bycatch: TED and BRD Technology

Another important area of collaboration between the NMFS and the INP has been in technology transfer of turtle excluder devices (TEDs) for shrimp trawls, and more recently, bycatch characterization and development of bycatch reduction devices (BRDs). Although technology transfer has been primarily tasked through the NMFS-Pascagoula (Mississippi) Laboratory through the fishing technology working group of Mexus-Gulf, the exchange has included individuals from the shrimp working group due to the application of excluder devices in the commercial shrimping industry.

Transfer of technology with respect to turtle excluders was especially important due to regulatory actions taken in the U.S. As a protected species, sea turtles are afforded protection in the U.S. from harassment, capture, or human-induced mortality by the

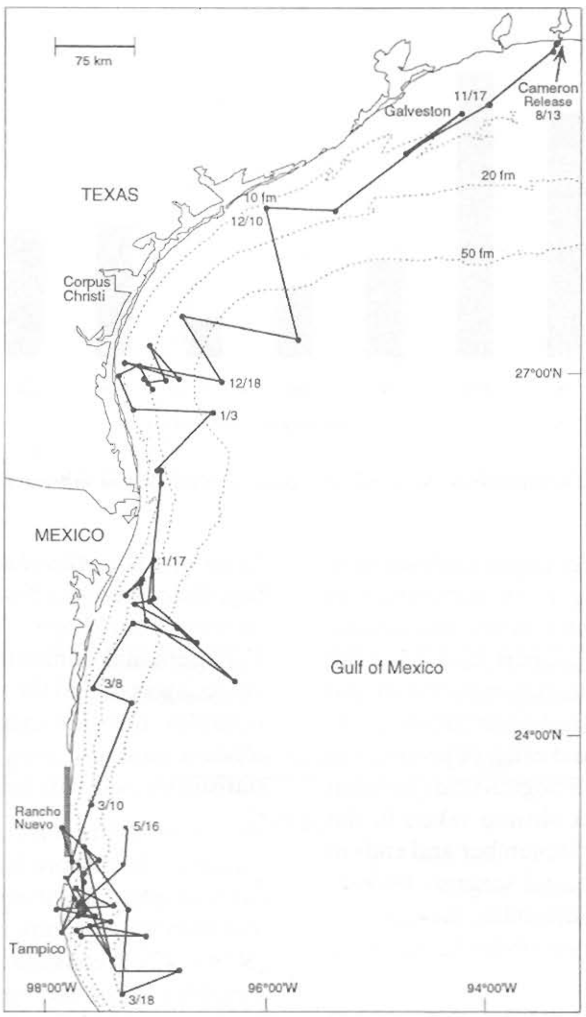

Figure 2. Movement of satellite-tracked Kemp's ridley from Cameron, Louisiana (USA) to Rancho Nuevo, Tamaulipas (Mexico), 13 August 1994 to 16 May 1995 (dates shown on track path). Solid dots represent location of turtle at time of signal transmission to satellite. Nesting of this Kemp's ridley as Rancho Nuevo was recorded on 23 April 1995, and again on 19 May 1995 (after transmitter failure).

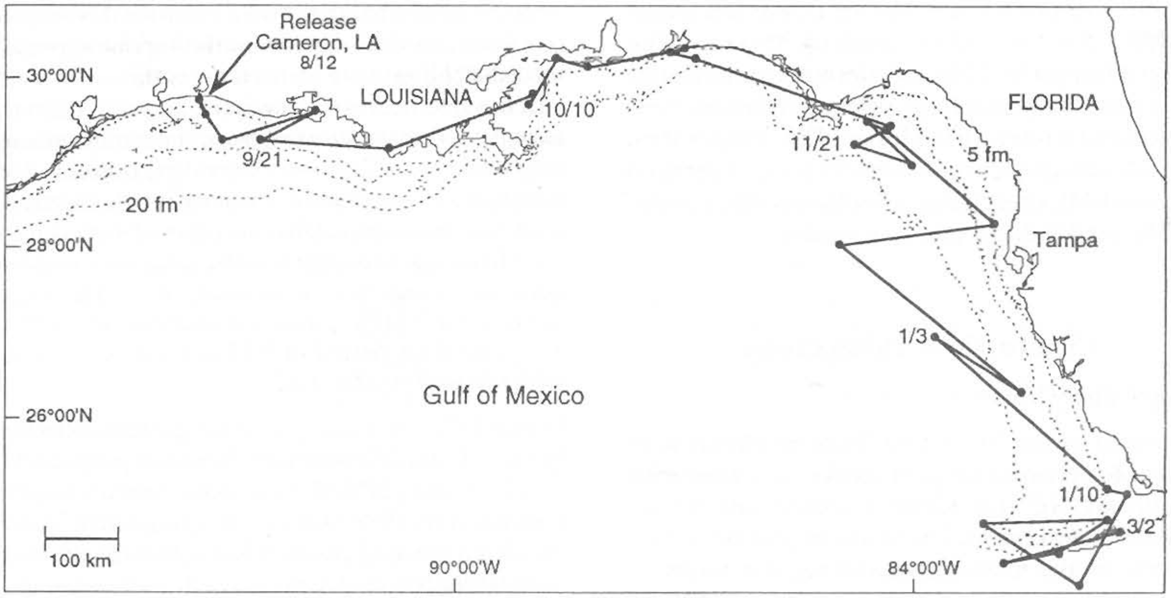

Figure 3. Movement of satellite tracked adult female Kemp's ridley (#7293, 65.6 cm SCL) from Cameron, Louisiana to south Florida waters, 12 August 1994 to 25 May 1995. Solid dots represent location of turtle at time of signal transmission to satellite. Recorded observations were of location class 0, A, or B, indicating possible error of ≥ 1 km.

Endangered Species Act. In the mid-1980's, all commercial shrimpers in the U.S. were required to install and utilize TEDs, a device which ejected sea turtles from shrimp nets while minimizing loss of the targeted shrimp. As the mandate requiring TEDs was implemented, the U.S. government imposed an embargo on shrimp imported from countries that did not require the devices in shrimp fisheries. This embargo would have affected Mexican fisheries in particular, especially since there is a higher population of sea turtles inhabiting waters under Mexican jurisdiction and nesting on coastal beaches in Mexico. A number of workshops were conducted to discuss design, installation, and operation of turtle excluder devices in Mexico. Similar workshops are proposed to evaluate new gear designs and fishing techniques.

The issue of bycatch reduction has provided similar opportunities. In the U.S., bycatch reduction devices (BRDs) were required in May 1988 on all offshore shrimping vessels. The driving force behind BRDs is the observed decline in red snapper (*Lutjanus campechanus*) stocks. Commercial shrimping operations in the northern Gulf of Mexico were observed to maintain high catches and mortality of juvenile red snapper in trawls. This, in conjunction with overfishing in the U.S. commercial and recreational fisheries has been cited as the primary cause of decline in the red snapper populations (Goodyear, 1993). While not yet an issue in waters under Mexican jurisdiction, there is widespread interest and concern by scientists, managers and industry representatives in Mexico as to the use of BRD's. So far, the collaboration on this issue has been limited to an exchange of data on bycatch characterization studies, gear design and testing, and guidelines for implementation of the devices in the U.S.

Ecosystem Research

In 1996, at the request of the delegation from Mexico, the Ecosystem/Ecopath™ working group was added to the Mexus-Gulf program to promote the use of ecosystem principles in management of fishery resources. The idea for this working group developed from the growing use of the Ecopath™ software (Christensen and Pauly, 1992) to compile, analyze, and research the trophic and ecosystem-level interactions among fisheries and living marine resources in Mexico. To date, scientists from both countries, in conjunction with researchers from the University of British Columbia, the International Center for Living Aquatic Resources Management (ICLARM), and the Centro Interdisciplinario de Ciencias Marinas (CICIMAR) have collaborated in development of a Large Marine Ecosystem model (LME) for the entire Gulf of Mexico. The development of the LME includes numerous scientists from academic institutions, primarily those involved in ecosystem research in Mexico. This collaboration includes development of submodels for integration into the LME or exchange scientific information that will be used in development of models.

Sea turtle working group

Kemp's Ridley Headstart Program

The goal of the Sea Turtle Working Group is to promote recovery of joint stocks of turtles with emphasis on the Kemp's ridley sea turtle (*Lepidochelys kempii*). The headstart program served as one of the most active and regular forms of cooperative research among scientists from INP and NMFS. The Kemp's ridley is classified as an endangered species under the Endangered Species Act (ESA) of 1973. Kemp's ridley were once considered abundant in the Gulf of Mexico, but decline in the stocks continued over a span of five decades until less than 500 nesting turtles were documented at their primary nesting beach in Rancho Nuevo, Tamaulipas, México. The Mexican government initiated protection of the Kemp's ridley in 1966.

Through a complex arrangement in 1978 and included in the goals of the Mexus-Gulf program, individuals from INP, NMFS, the U.S Fish and Wildlife Service (FWS), the U.S. National Park Service (NPS), the U.S. Geological Survey (USGS), and the Gladys Porter Zoo (Brownsville, TX) cooperated to initiate a "headstart" program for hatchlings from the Rancho Nuevo nesting beach. Headstarting is the process by which hatchlings are collected as they exit the nests on the beaches and maintained in a protected environment until they have developed to a size where they are less vulnerable to the sources of mortality observed for young individuals. With respect to the Kemp's ridley, the headstart program usually included removal of eggs from nests, relocating them to special incubation areas, allowing them to hatch and imprint on protected beach areas, then moved to a rearing facility.

Mexico has supported the U.S. Turtle Head Start Program and other SEFSC sea turtle research efforts by donating Kemp's ridley eggs and hatchlings. Most of the turtles were "imprinted" at the Padre Island National Seashore of the NPS, near Corpus Christi, Texas, in hopes that they would return to this area to nest when they matured. During the imprinting phase, turtle hatchlings were allowed to venture from local beaches into nearby Gulf waters, allowing them to assimilate chemical and environmental stimuli present in a certain area. The theory behind imprinting is that mature sea turtles retain a "memory" of the chemical/ environmental cues that they are exposed immediately after hatching, and return to the same sites to nest. Once hatchlings were imprinted, the turtles were moved to the NMFS-Galveston Laboratory where they were raised for period of 9-15 months before they were released into the wild.

During 1978-1992, nearly 23,000 eggs were collected by the INP and delivered to the headstart program (C. Tim Fontaine, NMFS, personal communication; Fontaine *et al.*, 1989; Shaver, 1997). More than 20,000 have been released into the Gulf of Mexico after the headstarting process. Others were released after longer periods, depending on research needs and health condition of turtles. Through 1995, no turtles imprinted at the Padre Island National Seashore had returned there to nest (Shaver, 1997). However, coastal beaches in Texas historically served as nesting areas for Kemp's ridleys, and 4 wild (non-headstarted) sea turtles were found there in 1995 (Donna Shaver, USGS, personal communication). Since then, the number of Kemp's ridleys nesting on Texas beaches has increased each year, including headstarted turtles (Table 5). Documented nestings of Kemp's ridley sea turtles along the Texas coast included only data for confirmed observations. It is hypothesized that other nests may have gone undetected due to the lack of resources to provide full coverage of possible nesting areas in Texas (Donna Shaver, USGS, personal communication).

The headstart program was discontinued in 1992, at the recommendation of select committee evaluating the Kemp's ridley recovery program. The primary motive for discontinuing the experiment centered on the fact that no headstarted turtles had nested on Texas beaches during the first 14 years of captive rearing program. However, the data collected in recent years suggests that scientists and managers may have underestimated the amount of time required for headstarted Kemp's ridleys to reach maturity and return to imprinted sites (NMFS, 1994).

Protection of Nesting Beaches

Numerous agencies in the U.S. and Mexico are involved in protection of Kemp's ridley nesting beaches. In Mexico, the Secretaria de Medio Ambiente, Recursos Naturales, y Pesca (SEMARNAP) and the INP facilitate protection of the nesting beach in Rancho Nuevo, Tamaulipas. Seven sea turtle nesting beach camps are maintained along Mexico's coast protecting Kemp's ridley, green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and leatherback turtles (*Dermochelys coriacea*). Scientists from INP conduct patrols, with the assistance of the Mexican National Guard. Sea turtle nests (eggs) are relocated to an area protected by a fenced enclosure and monitored for hatchlings. Protection from predation by wild animals and poaching (or other human-induced mortality) is provided for nests until hatchlings are released or removed from the area. In Texas, biologists from the NPS, USGS, and several academic institutions patrol the beaches of Padre Island to identify and protect sea turtle nests. If turtles are observed during nesting, they are examined for presence of identifying marks or tags which would identify their area of release. Regardless, the Rancho Nuevo beach remains the primary nesting site for nesting Kemp's ridleys. On occasion, biologists from the U.S. have participated in patrolling the Rancho Nuevo beaches to learn the techniques utilized in Mexico and applying them in protection of Kemp's ridleys found in U.S. waters.

Tagging Studies

The use of tags to mark sea turtles has been extremely important in identification of year class, release sites, migration routes, and nesting areas. All sea turtles delivered to the headstart program and released in the Gulf of Mexico have been marked with a variety of tags (NMFS, 1994; Dickie Revera, NMFS, personal communication), including metal flipper tags, internal wire tags, PIT (passive integrated transponder) microchip tags, living tags, and transmitter devices (satellite, radio, sonic). In addition, personnel from INP and NMFS have participated in a cooperative tagging efforts since 1996, tagging over 13,000 hatchlings at the Rancho Nuevo nesting beach, using internal wire tags. The internal wire and PIT tags are located with a hand held magnetometer or similar detection device. The living tag is a small portion of white plastron tissue from a ventral abdominal scute that is transplanted or grafted to a scute on the darker, dorsal carapace. Through the Mexus-Gulf program, scientists have collaborated in the tagging process through sharing of tagging equipment and detection devices (magnetometers, PIT tag readers) and by establishing cooperative tagging efforts, similar to those performed for penaeid shrimp studies. Several tagging workshops were conducted by NMFS to demonstrate marking procedures and use of tag detection equipment. Comprehensive data sharing has allowed turtle biologists from both countries to analyze and evaluate results. It is expected that another 10,000 hatchlings will be marked at the Rancho Nuevo beach by the end of 1998.

Satellite transmitters have provided a wealth of information on sea turtle migration patterns (short term as well as seasonal), dive frequency and duration, and environmental data on turtle habitats such as water temperature (Gitschlag, 1996; Renaud, 1995; Renaud and Carpenter, 1994; Renaud *et al.*, 1995, 1996). With regard to the Kemp's ridley, the possibility of determining nesting migratory routes onto Mexican beaches, via satellite surveys, is also being investigated. Over 59 sea turtles have been fitted with satellite transmitters by the NMFS-Galveston Laboratory, including 51 Kemp's ridley, 4 loggerheads (*Caretta caretta*), and 4 green turtles. Only a few of these turtles were considered sexually mature. Although satellite transmitters have limited life, they have they have shown that Kemp's ridley sea turtles have a wide range of mobility. Two of the mature Kemp's ridleys released in the northern Gulf of Mexico have been tracked into waters under Mexican jurisdiction. One of these (identification # 7295), released in Cameron, Louisiana (USA) actually nested on the Rancho Nuevo beach in April and May of 1995 (Figure 2). Another Kemp's ridley (female, identification # 7293) captured in the Cameron, Louisiana (August 1994) area was found to have been marked with a flipper tag and previously released at Rancho Nuevo. The turtle was fitted with a satellite transmitter and tracked along the northern Gulf coast to the waters off south Florida (Figure 3).

Other

Protection of the Kemp's ridley and other sea turtles continues through continued educational efforts, TED/BRD testing, research on submergence physiology (blood chemistry, physiological thresholds, resuscitation, etc.), ecological interactions, genetic stock identification, migrations patterns, and nesting range. This research could not be accomplished without the agreement reached through Mexus-Gulf. Since the discontinuation of the Kemp's ridley headstart program, the Mexican government and INP have provided more than 700 hatchlings to be captive-reared for research purposes. With the continued cooperation under Mexus-Gulf, this vital research for protection of sea turtles could not be completed.

Future activities

Research continues into all factors related to shrimp fishery management, especially regarding stock assessment, forecast modeling, and ecosystem analyses. The issues of bycatch, and excluder devices will continue to be a dynamic area of future research and collaboration among U.S. and Mexican scientists. While the frameworks for management of individual fishery stocks in the U.S. and Mexico remain quite different, it is through sharing of common experiences on the science of fishery resources and their management that sustainability of these resources is achieved. Integration of ecosystem considerations and principles is an important area of future cooperation. Ecosystem principles have been applied extensively in Mexican fisheries research and NMFS is currently developing a national initiative on application of ecosystem principles in U.S. fisheries. The national initiative would require development of a Fishery Ecosystem Plan (FEP) by regional fishery management councils.

Cooperation with Mexico on protection of endangered sea turtles should continue in the future, especially since the primary nesting beach for Kemp's ridleys is within the jurisdiction of the Mexican territorial seas. Researchers on both sides of the international boundary should closely monitor the recent observations of nesting by headstarted Kemp's ridley sea turtles. Additional research on life history and habitat needs of sea turtles should be initiated in the Gulf of Mexico, hopefully with supplemental funding from other pertinent agencies and industries. Also, joint research for an assessment of the status of Kemp's ridley throughout the Gulf of Mexico should continue.

Further investigation is necessary on the impacts of the offshore oil industry on all living marine resources. Responsible development of offshore aquaculture needs to be encouraged and monitored. Most importantly, it is imperative that the Mexus-Gulf program remains a forum for sharing of information and knowledge on all natural resources and management issues occurring throughout the Gulf of Mexico.

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