Overview of Coastal Pelagic Species Fisheries Management Plan

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The Coastal Pelagic Species Fisheries Management Plan (CPS FMP) was proposed and implemented as Amendment 8 to the Northern Anchovy Fishery Management Plan, which was first developed in 1977, implemented in 1988, and amended several times. Amendment 8 was the most extensive amendment and resulted in the name change to CPS FMP. The impetus for developing Amendment 8 was an expression of concern by the State of California to the Pacific Fisheries Management Council regarding the increasing range of Pacific sardine to include British Columbia, Canada, and the Baja California, Republic of Mexico; the State's inability to implement transboundary international fisheries management, as well as, coordination of interstate fisheries management with Oregon and Washington. Another justification cited by California was the increasing involvement of fishing vessels from Oregon, Washington, and Alaska in the Southern California market squid fishery which was expanding at a high rate during the mid-1990's.

The CPS FMP added four species not covered by the northern anchovy FMP to include most of the species fished by the roundhaul fleet except for highly migratory species. Those covered by the CPS FMP:

Pacific sardine	*Sardinops sagax*
Pacific mackerel	*Scomber japonicus*
Northern anchovy	*Engraulis mordax*
Market squid	*Loligo opalescens*
Jack mackerel	*Trachurus symmetricus*

In this FMP, management is divided into "active" and "monitored" categories. Pacific mackerel and Pacific sardine are "actively" managed, requiring annual stock biomass assessments and setting of harvest guidelines (similar to a quota) based on MSY control rules (harvest formulae). The other "monitored" species are managed by the Council via annual status reviews and applicable management measures such as gear and area restrictions. An annual Stock Assessment and Fisheries Evaluation (SAFE) report will produced by the Council for all CPS stocks.

The CPS FMP is established as a framework process for operational aspects of management and revision. There are two mechanisms for promulgating change within the FMP: 1) a Point-of-Concern Framework used for resource or ecological issues and 2) a Socio-economic Framework for non-biological issues. Each of these mechanisms can be handled by the Council depending on potential magnitude as routine/automatic actions, notice actions, abbreviated rulemaking actions, or full rulemaking actions.

The CPS FMP establishes a limited entry fishery south of 39 degrees north latitude (Pt. Arena California) and a 125 metric ton landing limit for the four species of fish, but specifically does not include fishing for market squid. A five-year qualifying period (January 1, 1993 through November 5, 1997) was established during which a vessel must have landed 100 metric tons of CPS fish to obtain a permit renewable every two years. Permits are fully transferable during the year 2000 after which they transferrable only if the permitted vessel is lost, stolen, or incapable of fishing in a federal fishery. Sportfishing, bait fishing, and catches of less than 5 metric tons are exempted from limited entry provisions.

The general form for the MSY control rule for "actively managed" CPS stocks is designed to continuously reduce exploitation rate as biomass declines:

H = (BIOMASS-CUTOFF) x FRACTION

where H is the harvest target level, CUTOFF is the lowest level of estimated biomass above which a harvest is allowed and FRACTION is the fraction of the biomass above the cutoff that can be taken by the fishery. The default MSY control rule for "monitored" stocks sets ABC equal to 25 percent of the best estimate of the MSY catch level.

For Pacific sardine, the CPS FMP sets ABC based on estimated biomass for the whole sardine stock with CUTOFF equal to 150,000 metric tons, FRACTION between five percent and 15 percent (dependant on three year average water temperature), and a harvest target up to a MAXCAT of 200,000 metric tons (maximum harvest level allowed independent of estimated biomass). ABC is calculated from the target harvest for the whole stock and prorating the proportion of total biomass in US waters.

For Pacific mackerel the CPS FMP sets CUTOFF and definition of overfished stock at 18,200 mt and FRACTION at 30%. Overfishing is defined as any fishing in excess of ABC calculated using the MSY control rule. No MAXCAT is defined because the U.S. fishery appears to be limited to about 40,000 mt per year by markets. Harvest level is defined for entire stock in Mexico, Canada, and U.S. waters and U.S. target harvest level prorated based on relative abundance in U.S. waters.

There are several issues which are currently being deliberated by the Council mainly because the CPS FMP is new having been implemented January 1, 2000. Briefly those issues are:

1. Bycatch provisions: these are being redrafted for the plan to better describe bycatch in the CPS fishery,
2. Market squid MSY: a definition is being prepared,
3. Market Squid ABC: the 25 percent default rule is being considered for change possibly to a higher level,
4. Limited Entry Capacity or Number of Vessel Goals: these are being defined along with mechanisms for achieving and maintaining them,

5. Vessel Transfer Rules: being reviewed to exam whether they can be modified to better accommodate fishermen fishing in both the CPS limited entry fishery and the State of California's market squid fishery,
6. North-South Allocation: a separate CPS allocation for Oregon and Washington is being discussed.

The Effects of a Resurgent Sardine Population on Marine Mammals in the California Current

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There is relatively little in the marine mammal literature which indicates the importance of sardine in marine mammal food habits. This occurs because most of the food habits studies along the Pacific coast of North America have been conducted during the past 40 years while sardine has been in very low abundance. During this time the northern anchovy was the abundant forage fish in the California Current System and was well represented in the food habits of marine mammals.

The decline of the anchovy population and the resurgence of sardines during the last decade have created an opportunity for marine mammals in the California Current to utilize a prey species which has many advantages over anchovy. Sardines are distributed more widely than were anchovy, occurring at higher latitudes and both on the continental shelf and well offshore in more pelagic habitats. Sardines also have much higher energy density than do anchovy (sardines have 65% more energy in each unit of wet weight than do anchovy (Sidwell 1981). The wider distribution makes sardine available to marine mammals species that are more oceanic and have the center of their distribution at higher latitudes in the north Pacific.

In the presentation, we review the distribution and food habits of several species of marine mammals, both cetacean and pinnipeds, and make a case for marine mammal shifting their food habits to include significant amounts of sardine. We begin by reviewing the distribution of several cetacean species, humpback whales (*Meganapteris novenglis*), Dall's porpoise (*Phocenoides dalli*) and white-sided dolphins (*Lagenorhynchus obliquidens*) to illustrate that although these species are distributed both on the continental shelf and shelf break, white-sided dolphin and Dall's porpoise are also found further offshore where they can be expected to utilize more pelagic prey species. The diet of humpback whales is dominated by euphasids followed by several species of small forage fish. In the northern part of the California Current both white-sided dolphin and Dall's porpoise feed on small schooling forage fish, with anchovy being a dominant component of both species diet. Yet in areas where sardine was available at the time food habits studies were conducted, they played a very important role in cetacean food habits. This is shown most strikingly in a food habits study of Dall's porpoise conducted in the southern Sea of Ohkotsk where Walker et al (1986) reported that sardine occurred in 97% of the stomach contents examined. This occurred at a time when the sardine populations had recovered in the western Pacific, but when there were few sardine available in the California Current System outside of the small remnant population in Mexico. It seems clear that if sardines were present they were the preferred prey for Dall's porpoise. Because of the high energy content of sardine we suspect that both Dall's porpoise and white-sided dolphins have shifted to a major dependence on sardine throughout the California Current System where and when sardine occur.

In a study of California sea lion (*Zalophus californianus*) adult female foraging behavior conducted in 1995 and 1996 using satellite telemetry (Melin and DeLong 2000), we found that adult females tend to feed on the continental shelf during the summer breeding season and on the shelf and seaward over deep water during the winter, non-breeding season. During summer the predominant prey were market squid, Pacific hake, sardine and rockfish. During the non-breeding season when animals were feeding farther offshore, we recorded an increased dependence on Pacific hake and sardine and decreased dependence on market squid as principal food. Lactating female sea lions appear to switch to a fish dominated prey assemblage during the winter, even though squid is abundant and available in the northern Channel Islands as evidenced by the conduct of the commercial fishery during that season. The shift in foraging behavior apparently reflects that the high energetic demands of lactation were being met by shifting to high-energy content prey, predominantly sardine.

Northern fur seal (*Callorhinus ursinus*) populations that breed on islands in the Bering Sea and migrate to waters of the California Current during the winter have declined by more than 60 % over the past three decades. Causes of the decline are not completely understood. We advance a hypothesis that the resurgence of the sardine population provides a high-energy food source that will improve the general health of fur seals and lead to population recovery. We suggest that the improved health should be detectable and measurable in increased pup production and juvenile survival.

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The Development of a Precautionary and Economically Viable Sardine Fishery in British Columbia

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HISTORICAL

Pacific sardines are a transient visitor to Canadian waters migrating north from California in the summers and returning in the fall to spawn. Abundance in BC waters is dependent on two factors, the abundance of the northern California population and water temperatures off our coast. In years of high abundance and warmer waters, it is estimated that on average about 10% of the population can be found off BC during the summer between July and October.

Commercially, sardines have a long history in BC and constituted one of our largest fisheries. The fishery itself dates back to 1917 when 73 tons were caught and canned for the European war effort. This "canned fishery" continued until 1925 when regulations were amended to allow for reduction of the sardines. The average catch for the period 1917-1924 was 1,786 tons with a maximum catch of 3,992 tons, taken in 1921.

In 1925 a change in the fishery regulations allowed for reduction of the sardines and resulted in a rapid expansion of the fishery. Catches increased to 14,470 tons in 1925 and to 78,377 tons by 1931. The largest catch in any one-year occurred in 1944 when 80,504 tons were landed. The fishery was concentrated off the West Coast of Vancouver Island where 80% of the catch was taken. Small amounts were also caught in Hecate Straits, Queen Charlotte Sound and Georgia Strait. At the peak of the fishery there were 26 reduction plants situated on the WCVI between Barkley Sound and Kyuquot.

The fishery collapsed in 1947 as a result of changing environmental conditions and a high exploitation rate. In 1947 only 445 tons were landed and there were no recorded catches in BC until 1993 when 5 sardines were caught in 4 separate groundfish tows off Barkley Sound. In 1993 sardines were also observed in samples taken during the roe herring test fishery in Georgia Straits.

TEST FISHERY

In 1995, approximately 5,000 tons of sardines were identified in Kyuquot Sound on the West Coast of Vancouver Island. One of the local residents from the Kyuquot Indian Band requested through the Aboriginal Fishing Strategy that DFO issue an experimental licence to fish and market sardines. A licence for 100 tons was issued in 1996 to look at the potential for economic development in this community. Approximately 80 tons were harvested and delivered to Vancouver. Lack of knowledge by the harvester and processor regarding the transportation and refrigeration requirements of sardines resulted in a poor quality product and the fish were not suitable for commercial sale.

PILOT EXPERIMENTAL FISHERY

As part of a federal/provincial memorandum of understanding (MOU) on fisheries and seafood diversification, a pilot experimental fishery for sardines was proposed. A three-year pilot fishery was implemented in accordance to the draft Policy for Development of New Fisheries in BC. The policy requires a precautionary approach to fisheries development that collects biological, by-catch, and fisheries information to support sound fisheries management decisions. To address quality issues experienced in the previous test fishery, participants in the experimental fishery had to demonstrate a knowledge of the species, and have suitable vessels which provided adequate storage conditions for the catch.

In November 1996 DFO, along with the Provincial Ministry of Fisheries (MOF), initiated a pilot fishery to further develop the potential for sardine as a commercial fishery. Six additional licences were issued for a three-year period. The licences were given to individuals who had written to DFO expressing an interest in exploring the potential for this fishery and had carried out some initial research into possible markets and methods of handling the sardines to ensure high quality standards. Initially, each applicant was issued an experimental licence for 80 tons annually for the three-year period (1997 –1999).

The initial year (1997) of the fishery consisted of a few small landings for market demonstration purposes, stock assessment and biological assessments. A total of 35 tons of the 560-ton quota was harvested for commercial purposes.

The second year continued with stock assessment activities, and the development of a research and quality control program for handling of catch on vessels to meet the stringent standards established by the potential customers. The fishery engaged in a full-scale commercial operation to supply niche markets that had been identified and secured the previous year. The fishery was conducted between September and December, when fat content and quality are maximised to achieve top market value. Landings for the 1998 fishery were 565 tons.

In order to further develop the potential for this fishery and test additional market opportunities, the individual quota of 80 tons was increased to 160 tons in 1999 bringing the total TAC to 1120 tons for the seven licence holders. The rational for this increase was based on the assumption that additional raw material was required to provide some confidence to the buyers that this fishery will be developed on a sustainable basis. In addition, the processing sector required extra product to justify expenditures for necessary processing equipment. It was also believed that the small increase in TAC would be well within the guidelines for precautionary development of the fishery.

Market Opportunities

While all age classes are represented in the BC sardine population, there is an abundance of larger older fish in the migratory population. Samples of individual fish have averaged 160 – 200 g. by weight, with some samples over 225 g. These large fish are creating interest in Japan, Korea, Taiwan and Australia. The Japanese market potential is for sushi while the Australian Korean and Taiwanese markets are for first class bait. The bait market is for feeding penned tuna in Australia and tuna longline bait. The longevity and magnitude of the market is presently unknown and further development if the market is required to assess the full potential for this fishery.

To-date buyers have indicated that the current potential market for BC sardines is in the 6,000 – 8,000 tons range provided fishers can deliver a high quality product. There is also some competitive advantage in the bait market because the average size of the fish caught in BC is considerably larger than that caught in California.

Quality Control

The fishermen and processors participating in the sardine fishery are finding the market very specific in terms of the quality of the product. Sardines are known for their tender skin and flesh and can be easily damaged through poor handling practises. To-date vessels capable of freezing at sea, having refrigerated seawater (RSW) or champagne systems have been able to land the best quality product. Superchilling or RSW systems have to be capable of holding temperatures at 28*F or lower and have sufficient refrigeration to prevent “spiking” any higher than 30*F. Freezing sardines, either at sea or at a fish processing facility also has to meet critical standards for successful marketing. The arrest period of latent heat during the freezing cycle (the period of time when a change of temperature cannot be recorded) should be less than two hours in order to produce top quality sardines. To assist with the further development of the fishery and achieve optimum market acceptance, DFO and MOF, in co-operation with the present participants are developing a manual which will outline quality control standards (guidelines) for on-board handling and procedures for shore-based processing

FUTURE DEVELOPMENT OF THE SARDINE FISHERY

The experimental sardine fishery is completing its third year and the Department is assessing the potential for expansion in the year 2000. The Pacific Stock Assessment Review Committee (PSARC) has carried out a review of the available sardine stock assessment information, and provided recommendations for the potential expansion of the sardine fishery. PSARC recommended that that the harvest rate for the British Columbia fishery will not exceed the US harvest rate.

Any expansion of this fishery must take into consideration two critical factors. The first one is that sardines in BC are transitory and there is no guarantee on how many will migrate to our coast in any given year. The last thing we want to do is set the stage for failure by issuing too many licenses. We must proceed cautiously and expand the fishery at a rate that allows for slow development. In years when we have cooler waters off our coast and very few sardines migrate up here we don't want a large fleet scouring the coast trying to catch the last sardine in the bay. This would not make sense for economic reasons but also from a conservation perspective as well.

The second factor relates to the economic viability of the fishery. The industry in still in the process of trying to establish a niche in the world market for sardines. If we expand too fast we could end up with a number of vessel landing poor quality sardines. This could have a long term detrimental affect and jeopardise our ability to market the fish.

The primary goal for expansion is to set the stage for developing an economically self sustaining market driven fishery. To this end we should be looking at a 2000 quota of about 5,000 tons. This would allow for a modest expansion of the fishery to somewhere around 25 vessels while still maintaining a precautionary harvest level.

Analysis Of Sardine Markets

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Introduction

This presentation will investigate sardine markets from a global perspective and the role Pacific sardines, harvested off the U.S. west coast, play in the global market. I will start out by reviewing world harvests and production of sardines over the 1984-98 period. I will then narrow the focus to global production and trade of Pacific sardine. Finally, I will look at U.S. landings and trade in Pacific sardine, and conclude by noting market opportunities that potentially exist for west coast landings. The analysis relies on international harvest and trade data from the U.N. Food and Agricultural Organization's global harvests and trade databases; the Pacific Fishery Management Council's PacFIN Management Data Base for west coast sardine landings and the NMFS foreign trade data base for U.S. international trade in Pacific sardine.

Global Harvests, Production and Trade

Globally there has been an appreciable decline in overall harvests of small pelagics since 1994 (Figure 1), with sardines and anchovies contributing most to this trend. Global sardine harvests began a significant decline in 1988, falling 64% from 14.0 million metric tons to 5.0 million metric tons by 1998. The sardine decline was offset by a sharp rise in anchovy harvests starting in 1991. Anchovy harvests peaked at over 14.0 million metric tons in 1994, and by 1998 had fallen 64% to just over 5.0 million metric tons. Global herring harvests have also declined in recent years, while mackerel harvests have increased.

Following the pattern in harvests, global production of sardine products dropped more than 80% from 3.6 million metric tons to 0.7 million metric tons from 1988 to 1997. After a sharp drop initially, foreign trade in sardines has trended upwards since 1992 (Figure 2). Countries that relied on domestic harvests for the bulk of their sardine production before the decline have had to turn to foreign sources to supplement domestic production.

The decline in global sardine harvests has occurred almost entirely in the Pacific. This reflects the collapse in Japanese and South American sardine resources, even with the recovery of the Pacific sardine off the U.S. west coast. Harvests in the Atlantic and Indian Oceans actually increased between 1994 and 1998 (Figure 3). Japan, Chile and Peru have been the major harvesters in the Pacific, joined more recently by Mexico. Between 1984 and 1998, Japan, Chile and Peru depended on the Pacific for 100% of their total sardine harvests, Mexico 99%. In 1984 these nations accounted for over 80% of the sardine harvest from the Pacific; by 1998 their combined share had declined to just over 60%. Japan and Chile have suffered the most severe harvest declines; harvests by Mexico and Peru increased over the period (Figure 4).

The decline in Pacific harvests most noticeably reflected in the production of meal and oil and frozen sardines. Global meal and oil production decreased from 1.3 million metric tons in

1984 to about 0.1 million metric tons in 1997; global production of frozen sardines fell from 1.2 million metric tons to 0.3 million metric tons over the same period. As a share of total production, meal and oil fell from 35% to less than 15%, while frozen production held at about 40% of total production for the period after peaking at 63% in 1993 (Figure 5).

Japan, Chile, Peru and Mexico were the leading producers of sardine commodities over the 1984-97 period, averaging about 80% of total production. Japan was by far the leading producer, even though its total production fell from over 2.0 million metric tons at the beginning of the period to just over 0.3 million metric tons by the end (Figure 6).

International trade in sardine commodities is dominated by frozen sardines that are consumed directly or used in the production of a number of processed products. At the beginning of the 1984-97 period, Japan was the world's leading exporter of sardine commodities, primarily frozen sardines, with over 50% of the total (Figure 7). However by the end of the period Japan's share of global exports had shrunk to less than 5% of the total, with Ecuador, predominately canned sardines, becoming the new leader. Brazil and the Philippines, frozen sardines for canning, and Malaysia, canned sardines, accounted for the greatest combined share of global imports during the 1984-97 period (Figure 8).

U.S. Harvests and Trade of Pacific Sardine

U.S. harvests and trade of Pacific sardines are relatively minor from the global perspective. U.S. landings of Pacific sardines have climbed from virtually nothing in 1989 to nearly 60,000 mt in 1999 (Figure 9). The bulk of landings are destined for export, most of the balance goes into domestic markets for canned sardine.

Exports are primarily in the frozen form, although exports of fresh Pacific sardines rose from near zero in 1997 to almost 5,000 mt in 1999. Exports of preserved Pacific sardine have been relatively minor (Figure 9). Exports of frozen Pacific sardines increased significantly in 1995 and in 1998. By 1999 over 30,000 mt of Pacific sardines were being exported, mainly to Australia (Figure 10). The Philippines has been a major purchaser of fresh, U.S.-caught, Pacific sardines; more recently, Australia has become the primary export market (Figure 11). Western Samoa, Malaysia and Panama have been the major markets for preserved exports, although there is no consistent purchase pattern (Figure 12).

Price trends for U.S. exports of Pacific sardines have been relatively stable for frozen and preserved exports over recent years, but much more variable for fresh exports. The real price (1997 dollars) for frozen exports decreased over most of the 1989-99 period, but has held fairly steady at about $.20 per pound since 1995 (Figure 13). This reflects the dominance of frozen exports to Australia where they are used as lower valued animal feed in bluefin tuna grow-out operations. (As a rule of thumb, frozen prices greater than $.50/lb indicate human consumption.) The real price for fresh exports has been more erratic, indicating use for both human consumption, Philippines, Japan and others, and for non-human consumption i.e. animal feed in Australia (Figure 14). The real price for preserved exports has averaged about $.80 per pound over the 1989-99 period (Figure 15).

For most of the1989-97 period, the price (1997 dollars) of U.S. exports of frozen Pacific sardines was greater than the average global price (Figure 13). This was also true for fresh exports (Figure 14). This suggests a relatively stronger demand for U.S. frozen and fresh Pacific sardines in the global market, that there is a quality difference that makes these products more preferred. On the other hand, the U.S. price for preserved Pacific sardine exports did not differ as much from that of the global average during 1989-97, suggesting that preserved Pacific sardine products may be more of a substitute in the global market.

Concluding Comments

- Even though there has been a significant decline in global sardine harvests and production since 1988, global sardine commodity prices have remained fairly stable, even moving downward. This suggests that other species and products are being substituted for sardines in the major global markets, otherwise one would expect upward pressure on prices.

- In major sardine harvesting and producing nations such as Japan, production and exports have declined and imports have increased. The sardine sector of the economy would be expected to concentrate on the highest valued uses within the country. This may present market opportunities in countries that have relied on Japan for sardine exports, as well as within Japan itself.

- A comparison of U.S. Pacific sardine frozen and fresh export prices with global averages suggest that U.S. products are of relatively high quality.

- U.S. exports of frozen Pacific sardine have cornered the market for bluefin tuna food in Australia. The U.S. has shipping advantages in the Australian sardine fish food market, because reasonable freight charges and frequent service; Pacific sardines caught off the west coast are high in oil, and because they are caught close to shore are of higher quality which promotes rapid growth in bluefin.

- Mexican labor costs low, but lack freezing capacity therefore unable to supply substantial quantities of frozen sardines to Australian tuna farms. U.S. has advantage over Mexico due to reliability of source.

- Mexico also farms bluefin and this could become a significant market for California sardines in the future. Japan imports frozen sardine from U.S. mainly as feed for farmed yellowtail.

- Strong demand for large frozen sardines in hand laid boxes for tuna longline bait.

- Promote consumption of Pacific sardines for health and nutritional purposes.

Figure 1. Trends in global Coastal Pelagics Species harvests, 1984-98.

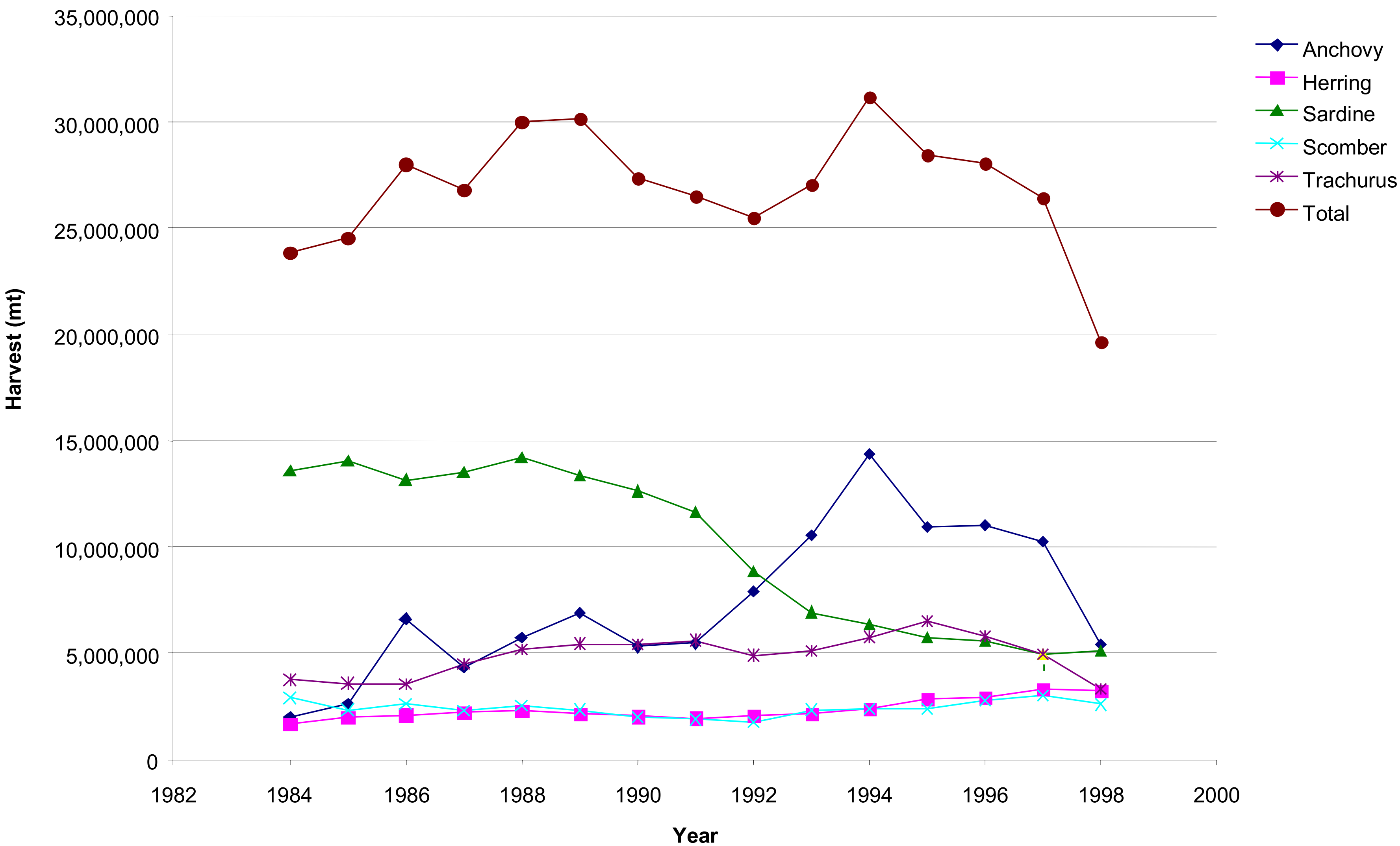


Figure 2. Global sardine harvests, production, exports and imports, 1984-97/98.

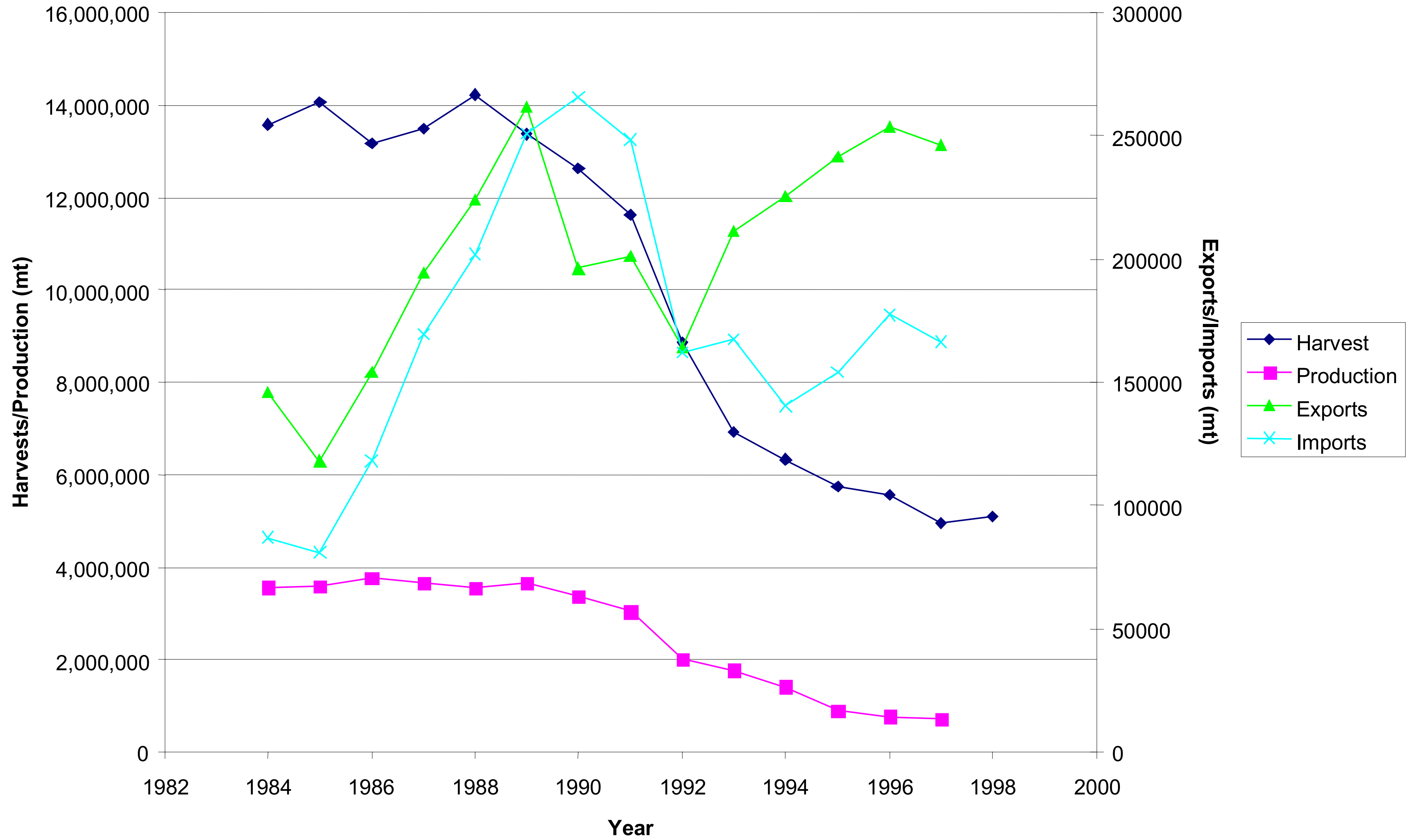


Figure 3. Global sardine harvests by ocean, 1984-98

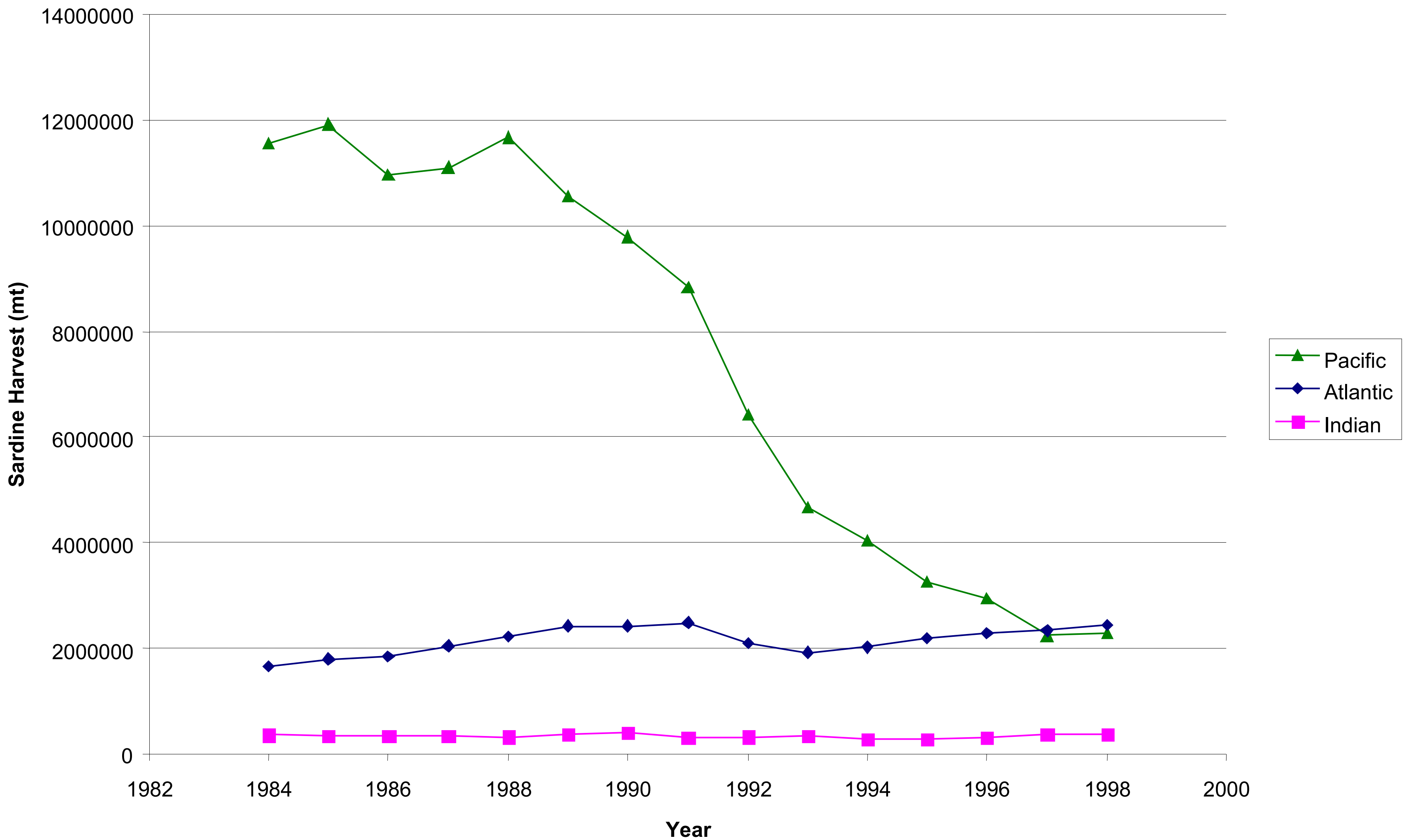


Figure 4. Pacific Ocean sardine harvest shares by leading harvesters, 1984-98.

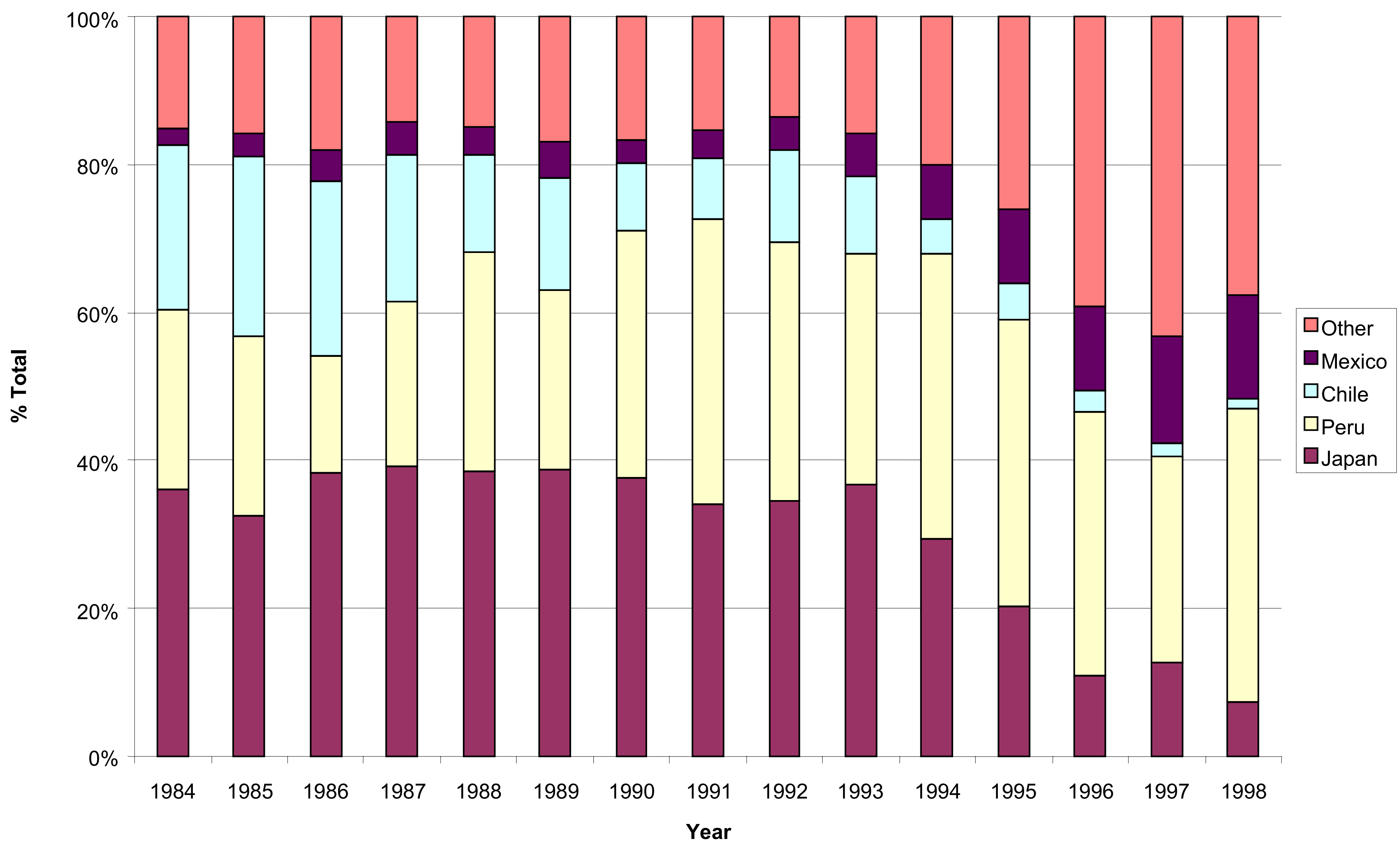


Figure 5. Trends in global sardine production, 1984-98.

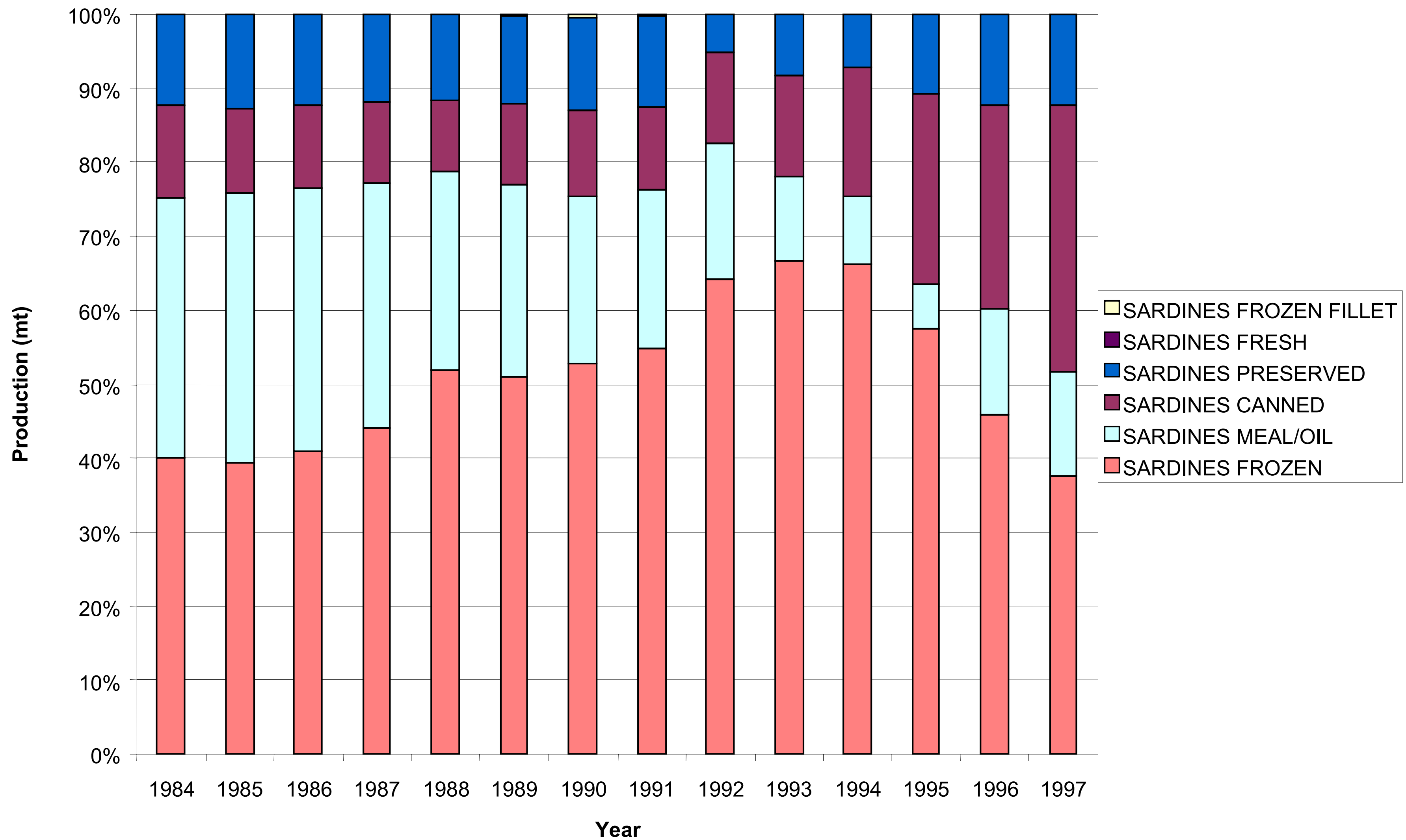


Figure 6. Global sardine production shares by leading producers, 1984-97.

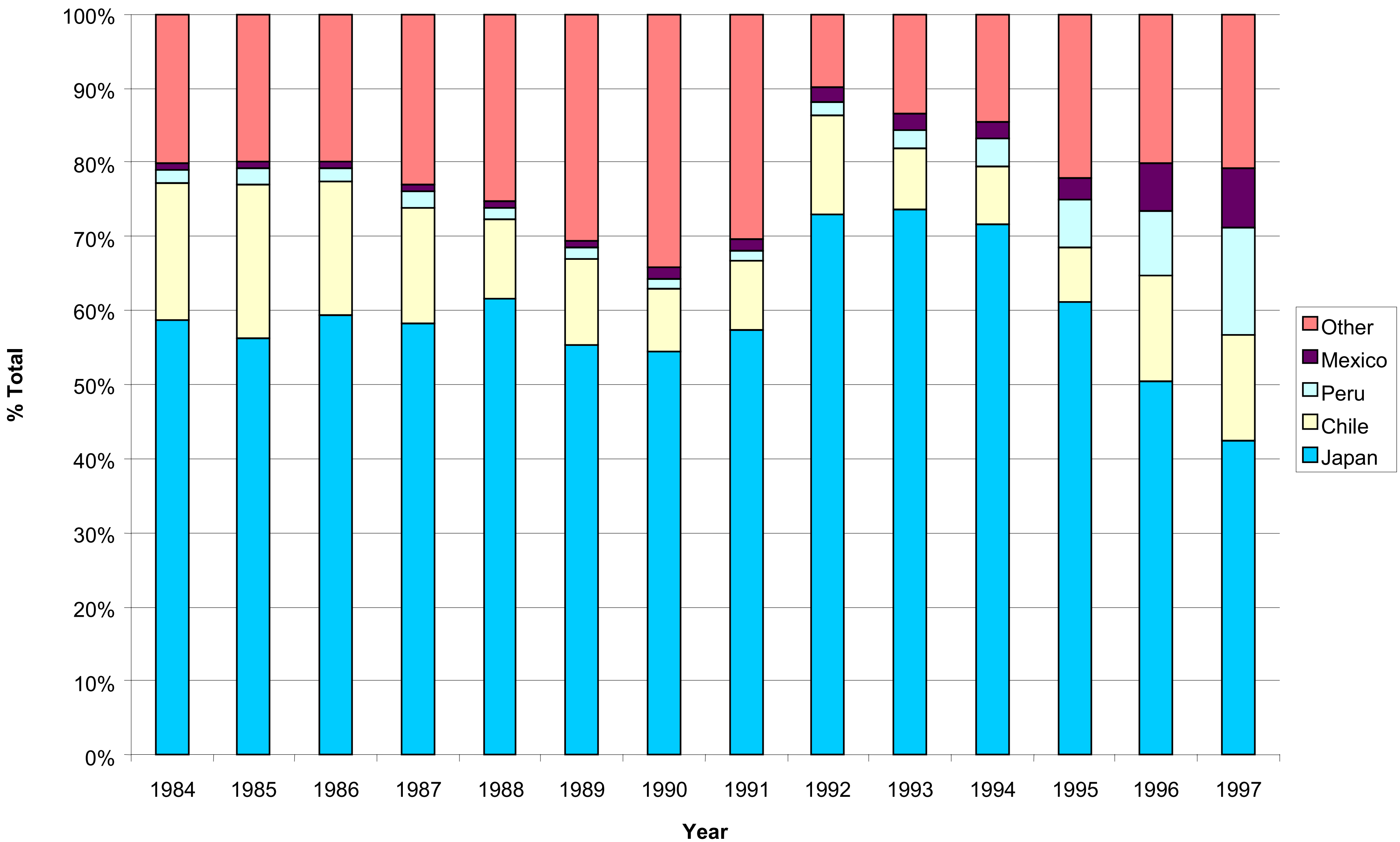


Figure 7. Global sardine export shares by leading exporters, 1984-98.

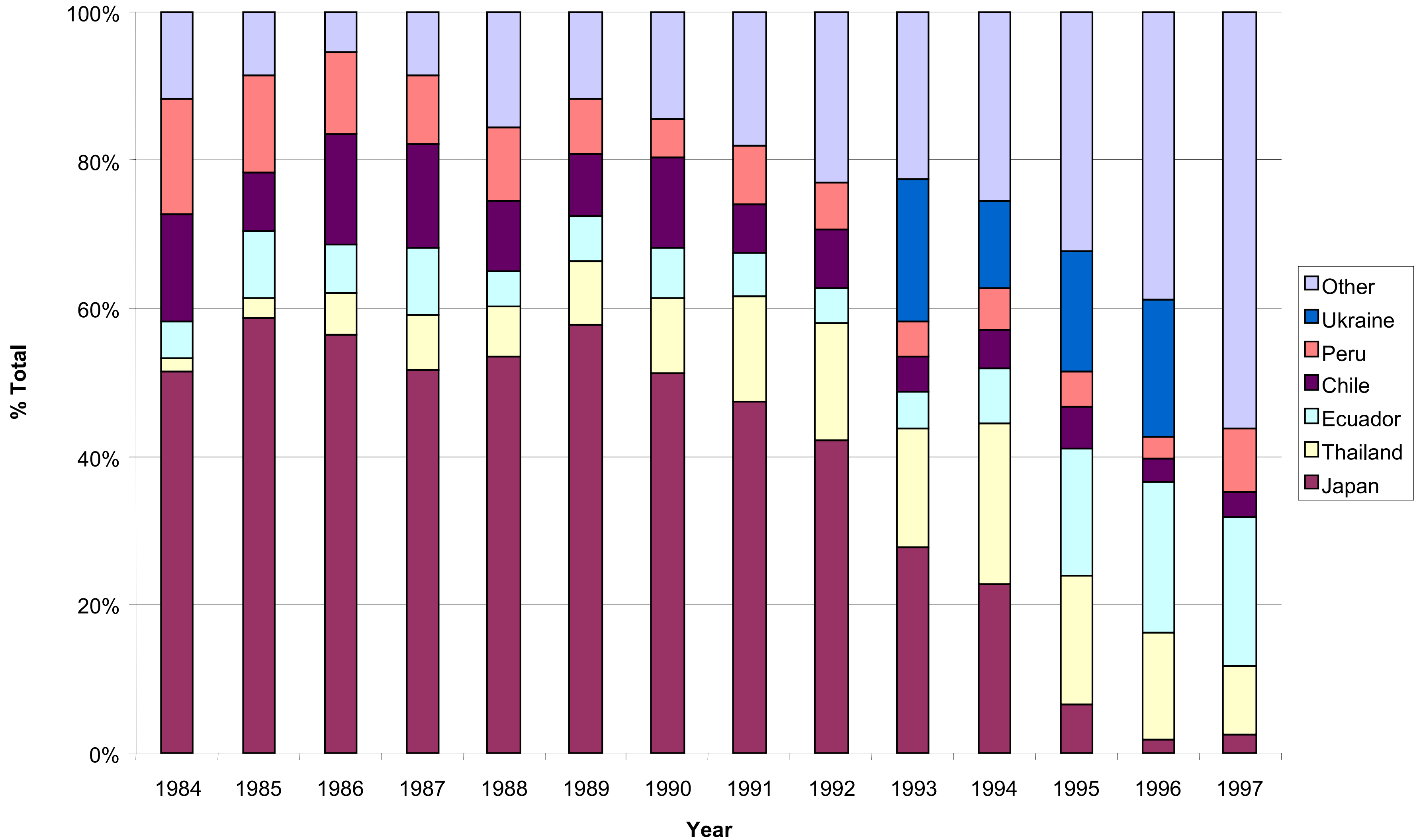


Figure 8. Global sardine import shares by leading importers, 1984-97

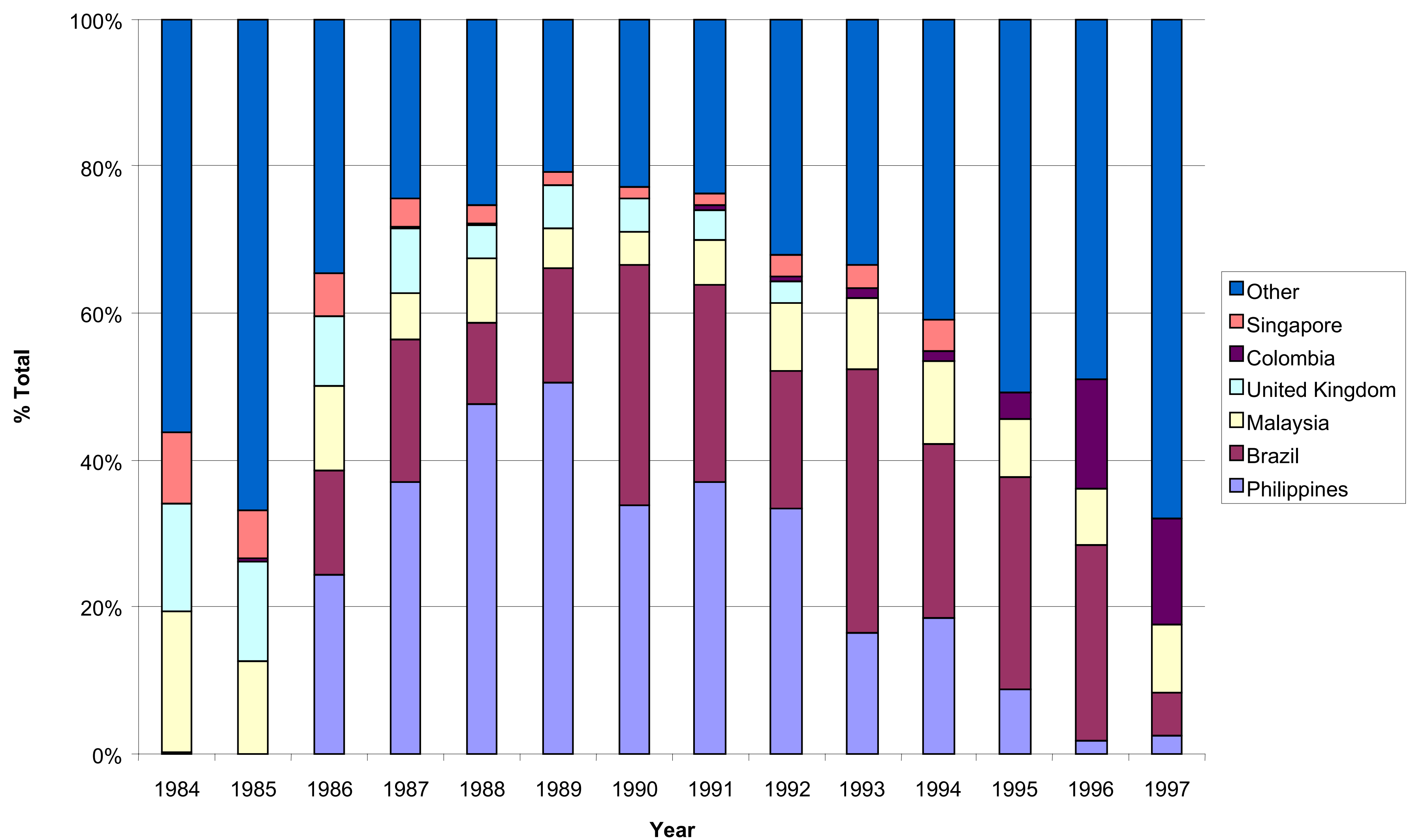


Figure 9. U.S. landings and exports of Pacific sardine, 1989-99.

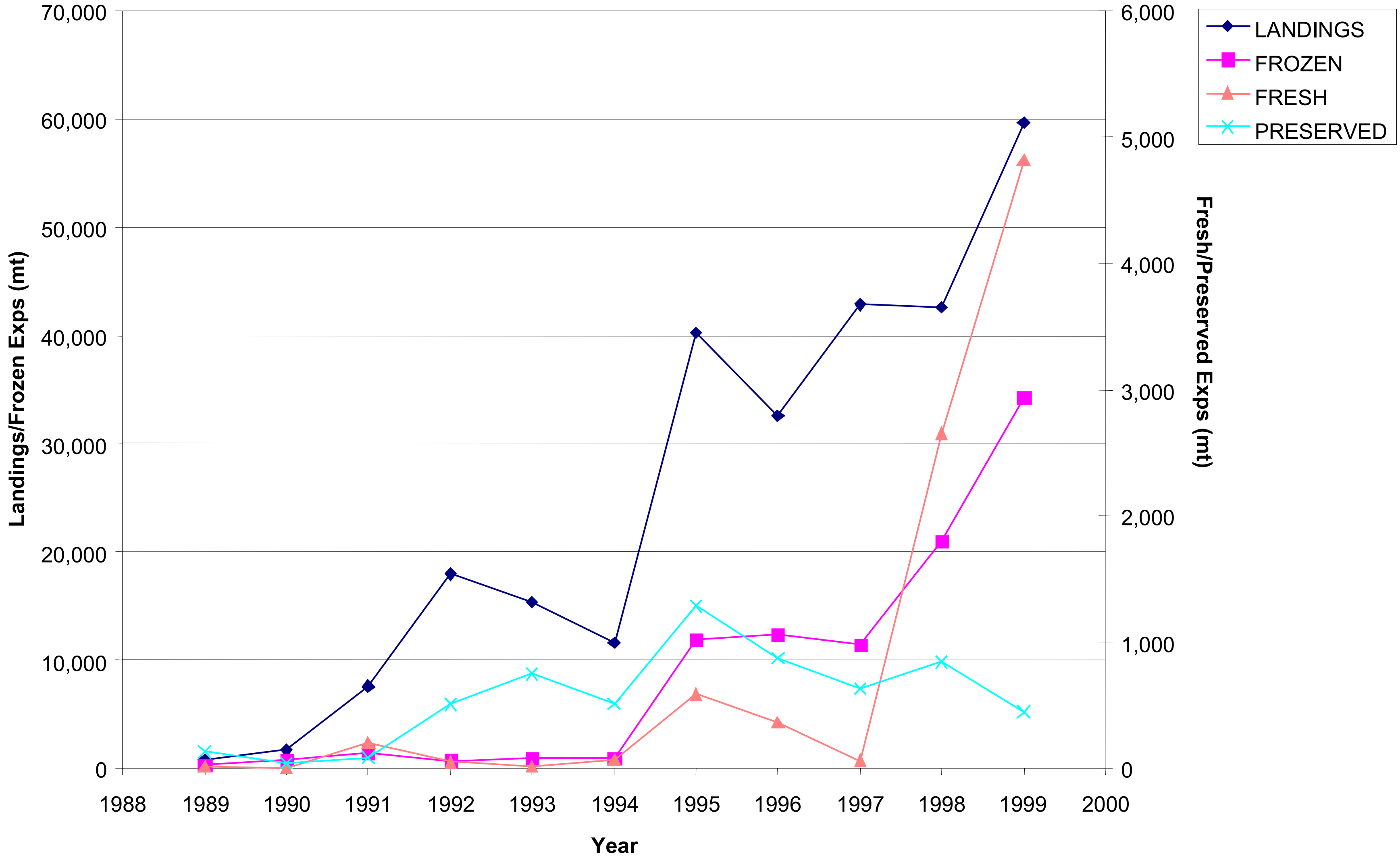


Figure 10. U.S. export shares of frozen Pacific sardine by major destinations, 1989-99.

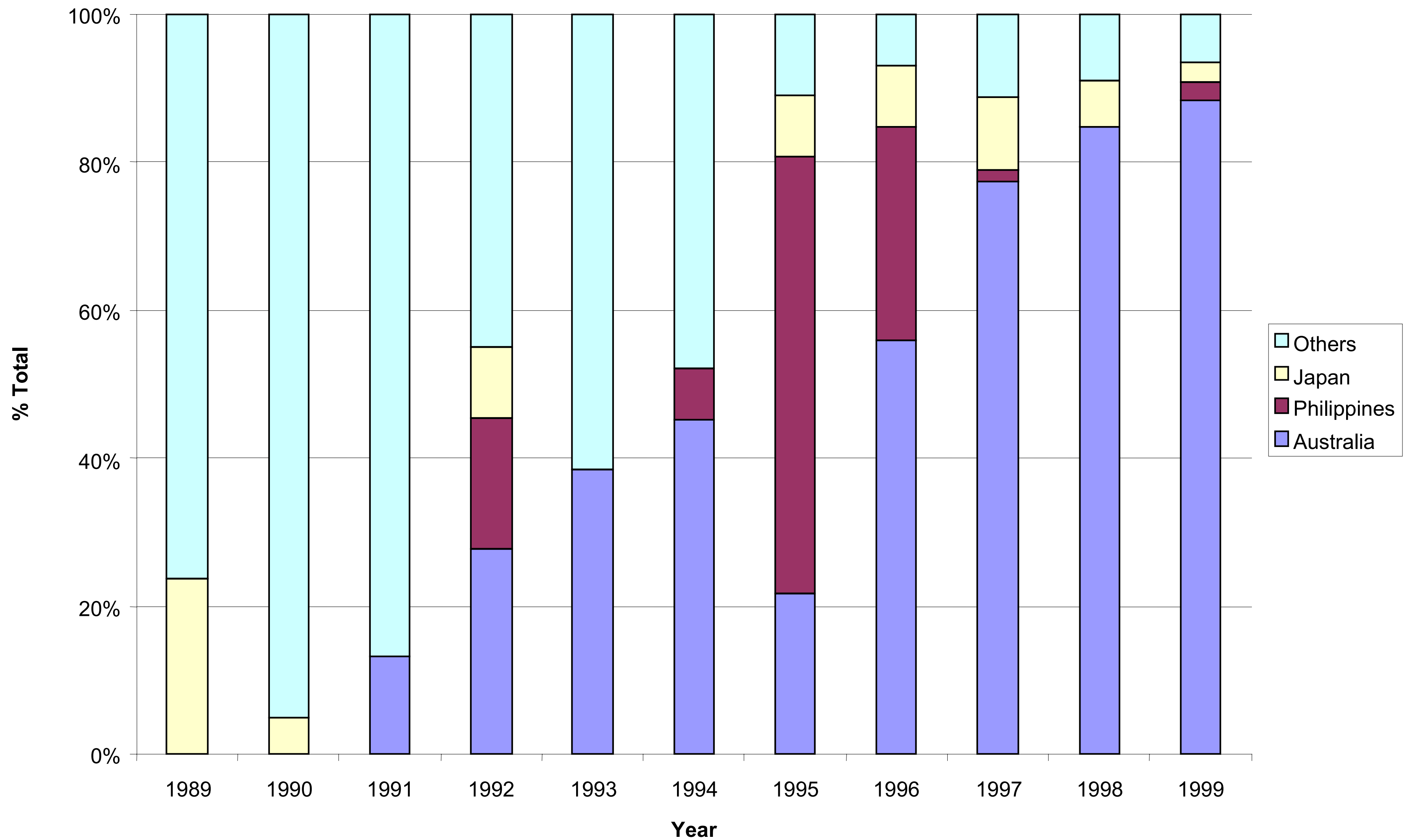


Figure 11. U.S. export shares of fresh Pacific sardine by major destinations, 1989-99.

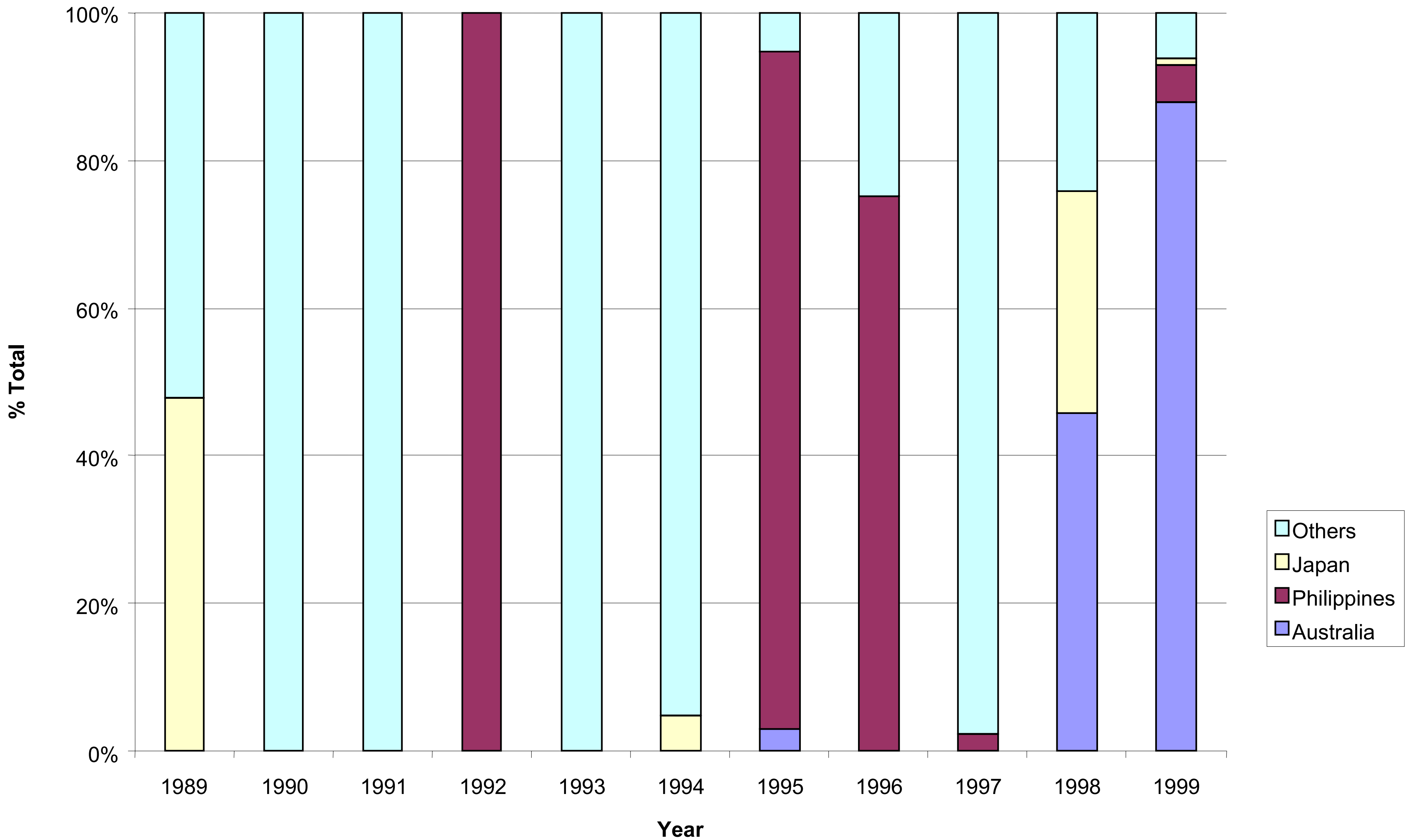


Figure 12. U.S. export shares of preserved Pacific sardine by major destinations, 1989-99.

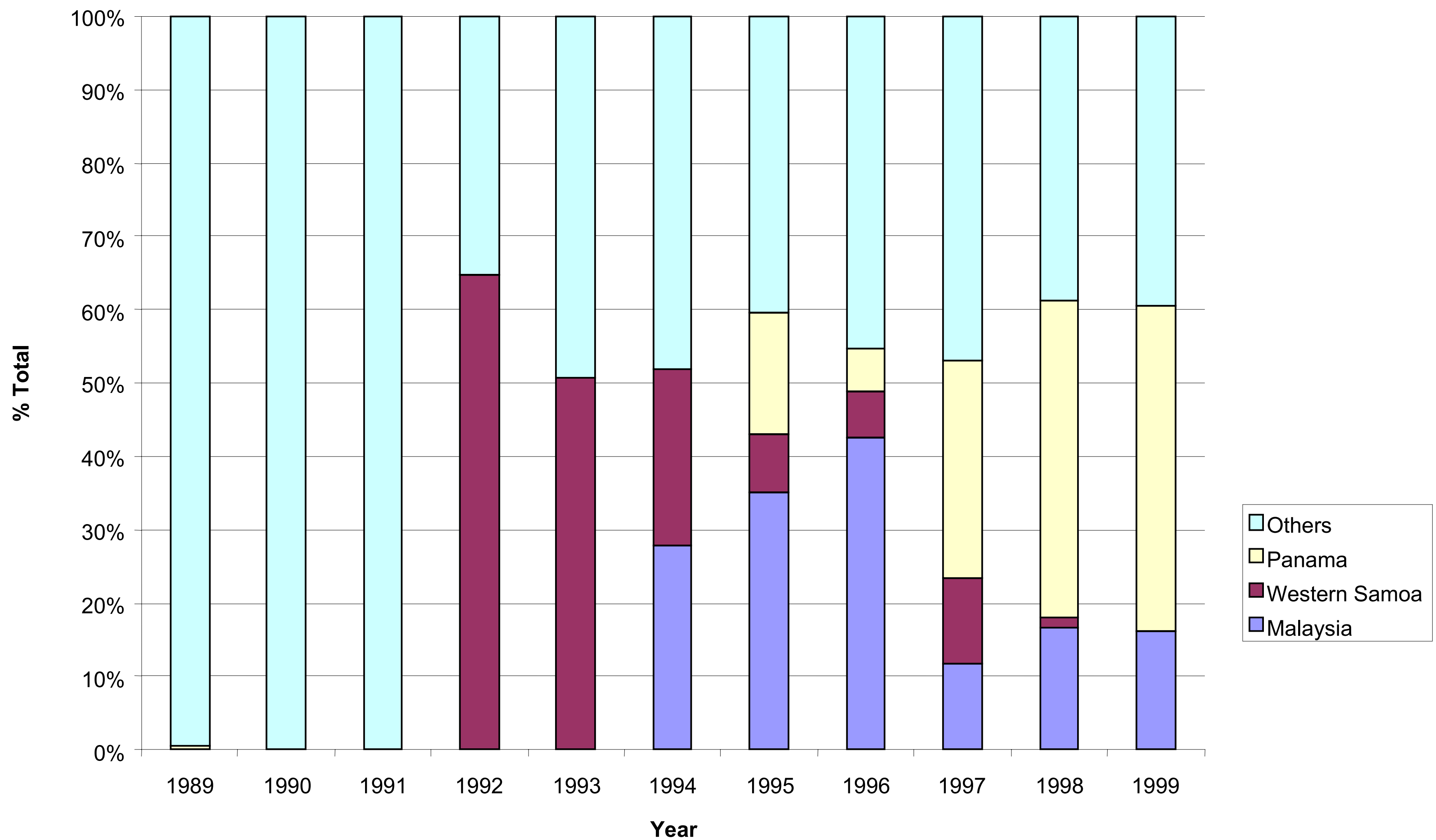


Figure 13. Trends in global frozen sardine export prices and U.S. frozen Pacific sardine export prices, 1989-97.

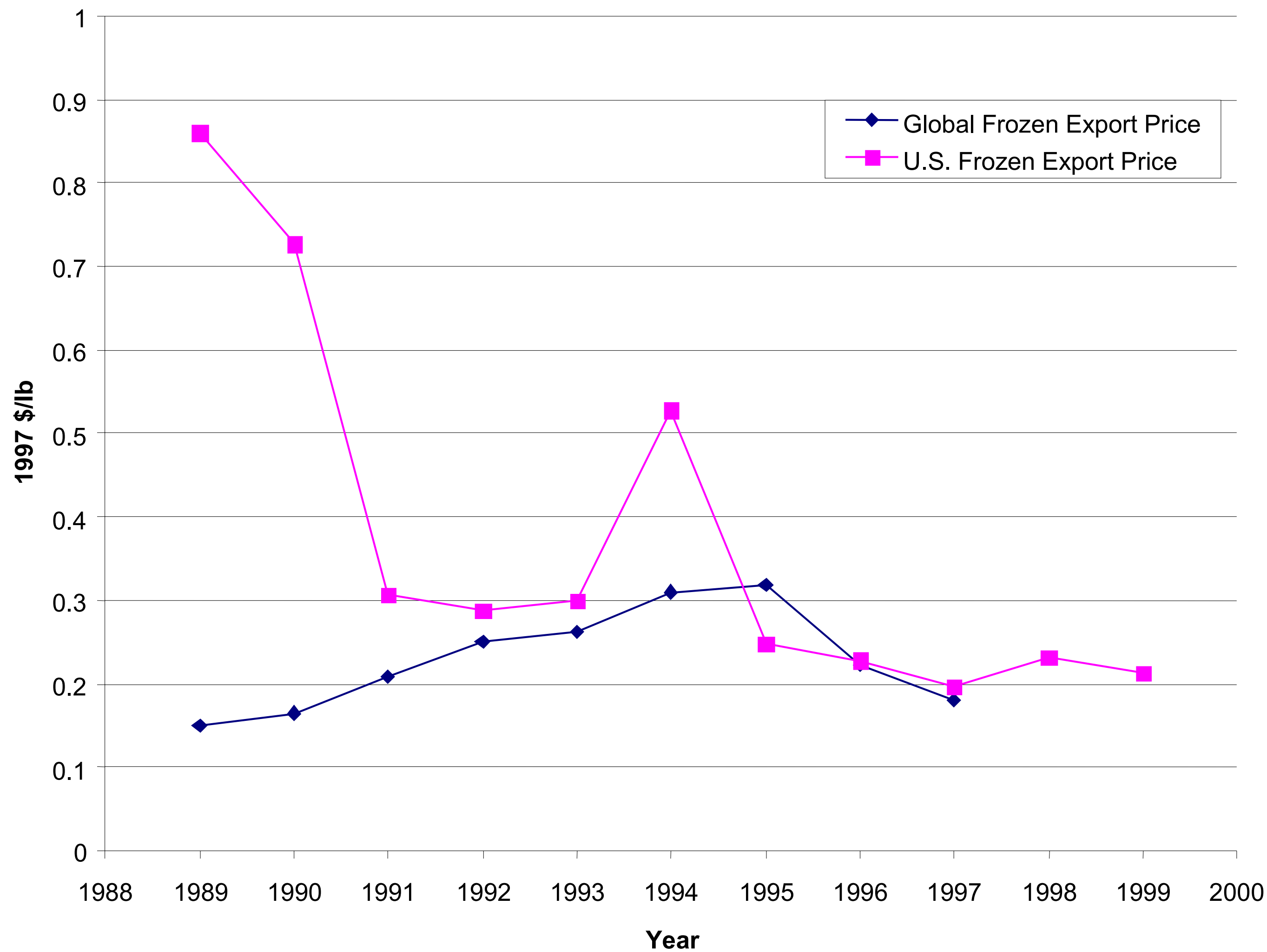


Figure 14. Trends in global fresh sardine export prices and U.S. fresh Pacific sardine export prices, 1989-97.

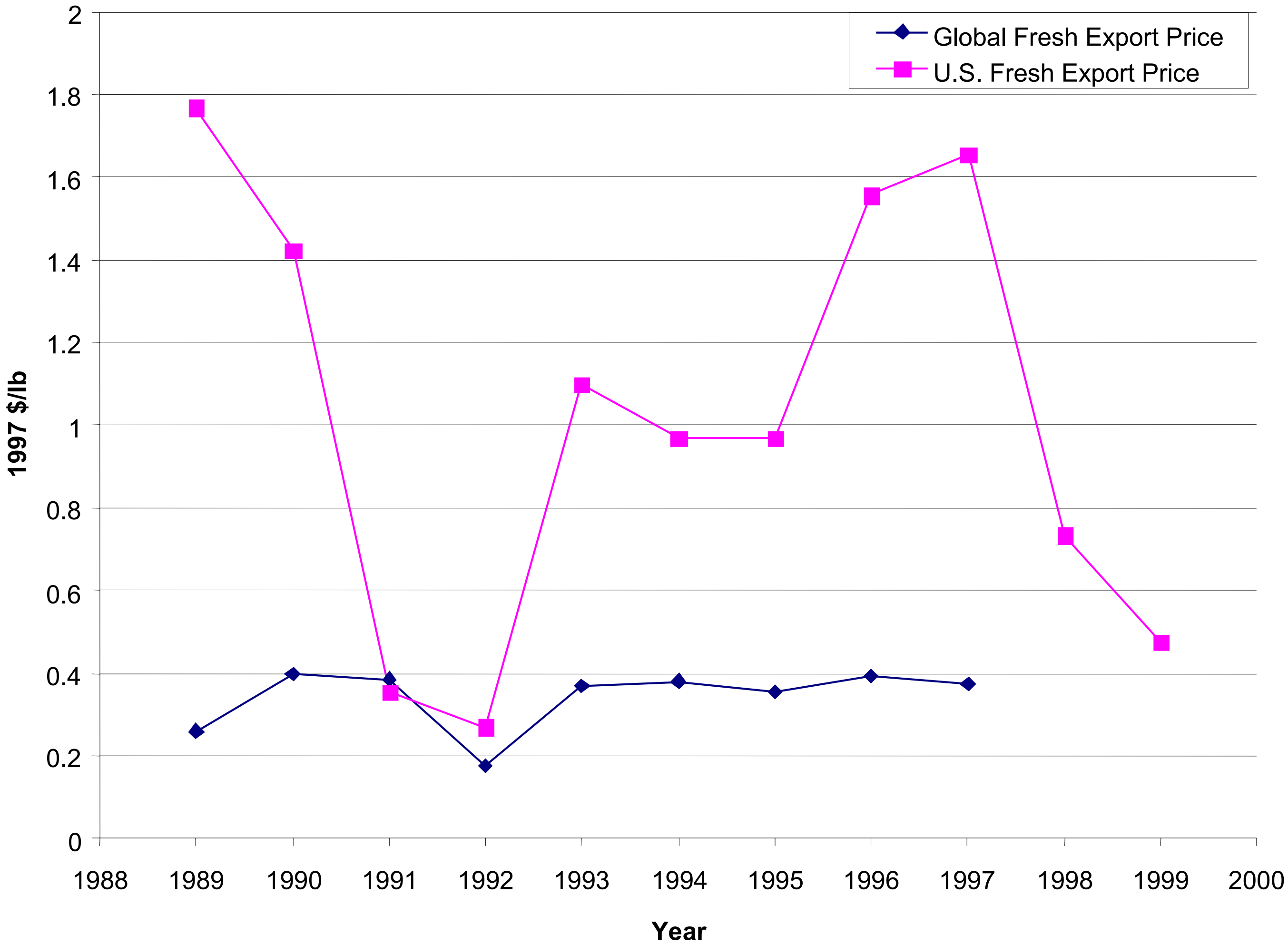
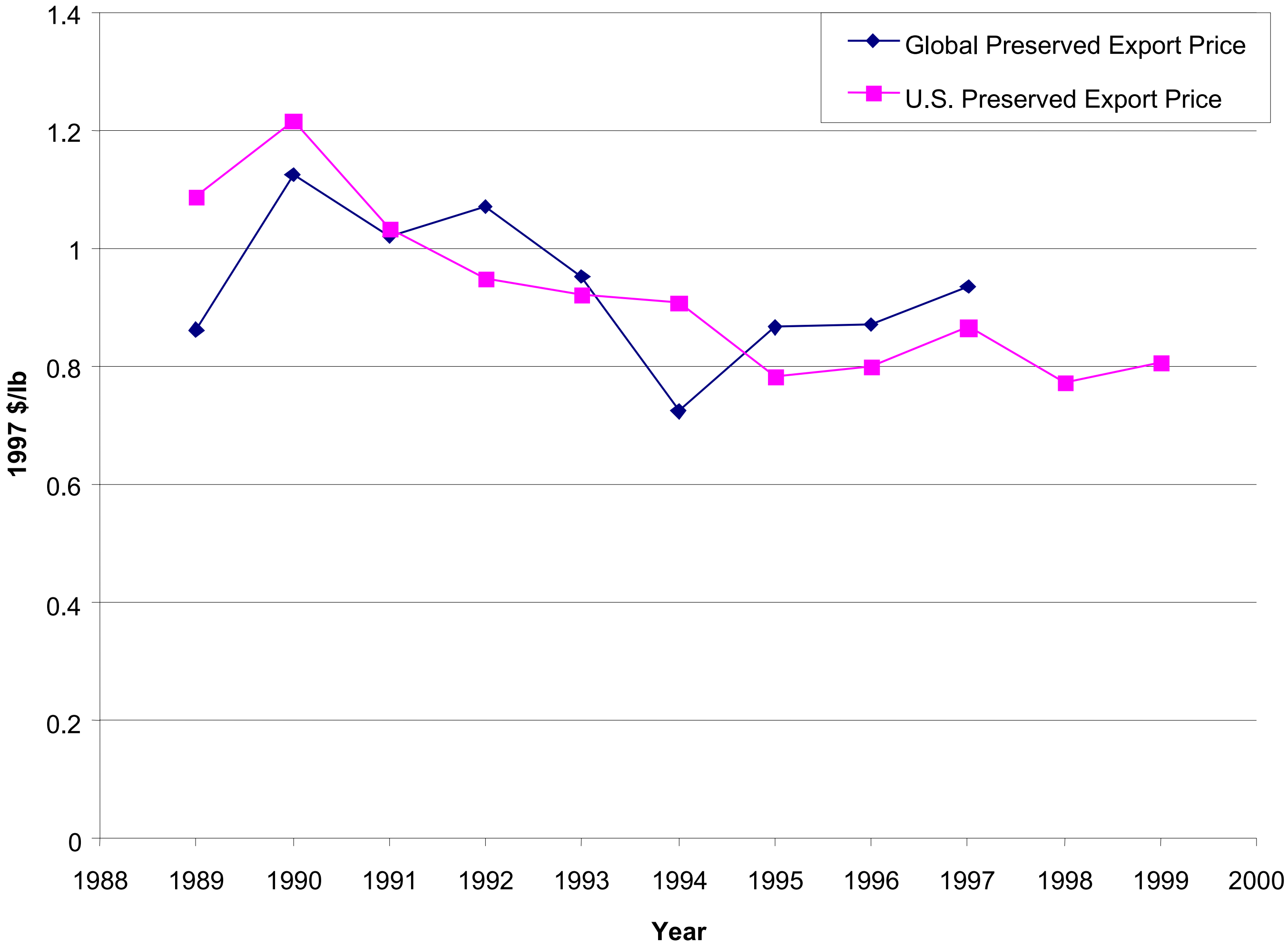


Figure 15. Trends in global preserved sardine export prices and U.S. preserved Pacific sardine export prices, 1989-97.



Acknowledgments

I would like to thank Steve Koplin, NMFS, Fishery Statistics, and Bill Jacobson, NMFS, Southwest Region for their assistance in assembling the data used in this presentation.

Fishing Industry Perspective

Don Pepper, Pacific Sardine Association, Richmond, British Columbia, Canada

Don Pepper noted that fishermen used the scientific information provided by the scientific community but that their information needs were simplistic. The BC situation was unique in relation to sardines as they were "fish of opportunity", appearing in BC waters when mature. Thus, indicators that predict their presence were needed. Stock dynamics, water temperature and range of the biomass were some on the indicators BC fishermen would like. Many of these are supplied but the desire for the "one true indicator" was still present.

From this perspective, fishermen want as little government intervention as possible and would only require the science. Management regimes unfortunately go from the science to socioeconomic objectives which leads to political solutions which may not always be the best for the biomass. None of this is new but it is a mantra that should be restated. Finally , conferences such as Sardine 2000 are important in getting "all the actors in the drama" in one place to exchange views and information.

III. WORKSHOP BREAKOUT SESSIONS AND RECOMMENDATIONS

Following the plenary session, the Symposium broke into two workshops: *Stock Assessment and Management* and *Ecosystem Consequences.* The groups were guided by the following:

- Develop recommendations on the formation of a coastwide network for modeling the dynamics of the sardine and monitoring their movements, geographic variation in vital rates, age structure, and abundance.

- Evaluate the potential ecosystem effects of the sardine outburst and determine the optimal research strategy for estimating the consequences of shifts in ecosystem dominance of sardine.

- Fishery/Economics and Management: Evaluate the economic value of sardines and potential value markets, ecological and management influences on markets.

STOCK ASSESSMENT AND MANAGEMENT WORKSHOP

John Hunter and Doyle Hanan, Chairs

Sardine fisheries exist once again along the entire coast of North America from Baja California Mexico to British Columbia, Canada. An accurate coast wide assessment of this widely distributed stock is not possible at present for a variety of reasons: 1) the fishery independent measures of abundance cover only a fraction of the full range of the population; 2) the sardine fishery takes only a near-shore, often younger, fraction of the stock leaving the offshore fraction, of presumably larger and older fish, un-sampled; 3) age and growth measurements are confounded by movements along the coast which are presently largely unknown; and 4) basic life table information are lacking or need validation. The group discussed a variety of measurements and monitoring approaches that would help remedy the situation but set no priorities (Table 1). It was considered unlikely that new money would be available to expand the extent of coastal monitoring and research on sardine throughout its range. Thus, future advances in stock assessment will depend upon pooling of information, and in-kind contributions from industry and fishery agencies. In this regard, U.S. and Canadian Fishing Industry representatives expressed a willingness to contribute to the coast-wide collection of information needed to assess the sardine population. Since neither the Mexican sardine industry, nor the Instituto Nacional de Pesca (INP) attended this session, the extent of their interest in this international collaboration is not known. Mexican academic scientists who attended the session strongly supported such an international collaborative approach.

The consensus of the workshop was that an international forum was needed to implement and coordinate coast wide collection of the data for sardine stock assessment, and to exchange information, and keep abreast of trends in the fishery. The forum, called here FISCIE for Forum for International Sardine Collaboration and Information Exchange, should have regularly scheduled annual meetings and be attended by industry, fishery agency and academic scientists from Canada, Mexico and the U.S. FISCIE would establish collaborative protocol, facilitate in-kind contributions from industry, share and archive information, coordinate coast-wide sampling periods or surveys involving industry and agencies, share and discuss the most recent stock assessment information, and provide coast-wide standards for measurements. An *ad hoc* steering committee was established for organizing the first meeting of FISCIE (Table 2).

Another issue discussed in this breakout group was the need to modernize the U.S. sardine fleet. Fleet modernization is needed for the fleet to meet Hazard Analysis Critical Control Point (HACCP) requirements, meet new environmental requirements such as a sea disposal of transport water, and to produce a higher quality and more valuable product. While fleet modernization is primarily a U.S. industry matter, beyond the scope of Sardine 2000, two appropriate science policy issues were identified. First, when control rules are considered for the sardine fishery by U.S. management, the need for fleet modernization should be considered as a value as well as the traditional conservation-based value of reducing fishing effort. The group recommended that this report draw attention to this issue to scientists and managers involved in U.S. Coastal Pelagic Fish Management. Secondly, it would be advantageous to consider upgrading the collection of fishing information using shipboard electronic data logging systems as part of such a fleet modernization program. Presently, agency biologists are working with data collecting systems as obsolete as the fishing vessels.

ACTION ITEMS

1) Convene first meeting of FISCIE.

The goal of the first meeting shall be to identify and implement collaborative data collection for coast-wide stock assessment of sardine. The meeting shall be convened in 2000 and shall:

- Elect a chair and establish meeting procedures.
- Hear views of INP and Mexican sardine industry regarding joining FISCIE.
- Inventory all west coast sardine data sources.
- Identify and set priorities for new information collection.
- Implement a coast-wide (US, Mex., and Can.) data collection initiative for 2001.
- Establish an electronic reporting and information system.
- Present and discuss latest stock assessments.
- Exchange information on trends and events in the fishery.

2) Implement Coast-wide collection of oil yield data. The oil yield of sardines routinely estimated by processors, could provide a valuable time series for monitoring the condition of the stock, if the data were routinely archived, and the methods presently employed were intercalibrated. Steps shall be taken to begin this process.

Table 1. Research activities suggested by the working group that would increase coast-wide knowledge of sardine needed for a coast-wide stock assessment. Practicality of items were not determined and no priorities were set; items are listed in no particular order.

Increase sampling for age structure in northern and southern end of the range.

Convert Oregon-Washington egg surveys carried out by NWFSC to biomass by estimating adult parameters (batch fecundity and spawning frequency).

Improve existing southern California spawning biomass estimates based egg surveys by measuring adult spawning parameters (batch fecundity and spawning frequency).

Conduct aerial surveys of sardine schools using spotter pilots to provide coast wide indices of sardine abundance and estimate the extent of offshore distribution.

Add airborne school detection using lidar to the above aerial surveys.

Conduct coast wide inventory of sardine biomass using CUFES.

Conduct acoustic-trawl survey coast wide to provide coast wide estimate of biomass.

Carry out an industry/agency tagging program using conventional tags or button archival tags. (Idea not well supported by group because of expected low return rates and costs).

Conduct a coast-wide intensive sampling periods using industry and multiple agency contributions resembling the URICA biomass surveys of Peru, except the focus would be on age structure and reproductive rates. One suggestion was to focus on the April since the April CalCOFI survey provides the longest fishery independent time series for sardine; a summer focus would also be useful since the northern fishery occurs in the summer.

Conduct short fishing vessel cruises to establish offshore limit to sardine distribution and to obtain age structure information.

Examine micro-constituents of sardine otoliths to determine the origins of fish (a low cost alternative to tagging).

Implement electronic logbooks with GPS and time stamp to improve locality and time data on catches.

Establish a network to archive industry derived estimates of size specific oil yield to be used in estimating seasonal reproductive output of stock.

Investigate feeding selectivity and the role of diet to determine the causal factors of bursting abdomens (the hot tummy phenomena).

ECOSYSTEM CONSEQUENCES WORKSHOP

Gordon Swartzman, Chair

Recommendations

I. Convene a National Center for Ecological Analysis and Synthesis (NCEAS) workshop addressing development of an Individual Based Model (IBM) for examining the relative importance of temperature and advection (regime shifts), predation, and the fishery in bringing about expansion and contraction of the E. Pacific sardine population. The benefits of having an NCEAS sponsored working group coordinating model development are:

- We will develop a format and protocol for data sharing; currently the data have been collected by a variety of organizations and are not easily transportable;
- We will set standards for future data needs and help design experiments to fill in major areas of missing data;
- We will coordinate research efforts now done separately and piecemeal by researchers from Mexico to Canada;
- We will pursue a coordinated effort to obtain funding to code and run the model;
- We will develop (specify) the model in the context of existing ideas about the expansion and contraction of the sardine population and will provide a framework for examining the implications of the various hypotheses;
- We will specify model scenarios and discuss model output in workshop format;
- The model might be used as a basis for a comparative study of sardine populations around the Pacific Rim. One important question it might address was why the NE. Pacific sardine population did not expand its range north in during the 1970's, in conjunction with expansions in range of the other Pacific sardine populations.

II. Add-ons to existing sampling programs or ships of opportunity

We suggest the addition of several new procedures to be done with existing sampling programs (BPA, GLOBEC, NMFS triennial, bait fishery, Mexican juvenile surveys) including:

- Collecting samples for micro-satellite genetic comparisons of stocks, including comparison with the 1940's NE Pacific Sardine stock;

- Record tissue and gonad condition, in addition to weight and length, in port sampling protocols. This would help with improve the migration component of an IBM and provide useful information related to reproductive activity;

- Stable isotope analysis of samples, including historic samples to provide insight in possible changes in diet of sardines during the expansion or contraction phases;

- Obtain forage fish energy content and condition factor over a range of species. This would provide information on the importance of energetics and food resources to changes in sardine population abundance;

Discussion:

Theories on causes of expansion and contraction of the sardine fishery

Are there specific conditions precipitating the California sardine crash/expansion? Consider conditions allowing a geographic expansion (invasion) vs. conditions allowing a numerical expansion (persistence). We reviewed evidence given in talks by Sandy MacFarlane, Ruben Sanchez-Rodriguez, David Checkley and John Field. Various decade-scale/regime shifts in 1925, 1947, 1977 and 1989 provided correlative evidence. Why was there no response of California sardine in 1977 when both Peruvian and Japanese sardine populations expanded then? Perhaps comparative studies with other Pacific sardine stocks would help explain sources of expansion/declines. Shifts in sardine population abundance north and south appear to depend on both conditions for spawning and feeding. Temperature interacts with advection in that the sardine spawning areas are limited by temperature, while advection must be present to allow northward migration of juveniles and adults. Also, regime shifts can produce differences in prey species mix that can affect grazing success of adults and resultant gonad development. Contraction may accompany cooler temperatures that prevents reproduction in the northern part of the range (i.e. Canada), and results in poor food resources north of Baja California. The population may move south in cooler conditions and replace tropical foraging species that had moved north under warmer conditions. Thus expansions and contractions may be associated with changes in temperature, advection and food availability. These in turn may influence spawning habitat, fecundity/body condition, juvenile survival and adult migration patterns. All are thought important. Other factors of possible importance are the influence of predators and the fishery in the decline phase?

Modeling

We reviewed the ECOPATH model. Bob Francis described, in lay terms, how ECOPATH computes trophic efficiency given biomass, production, and consumption and diet composition for each component. In our opinion the ECOPATH model seems over-determined. The whole modeling exercise is balancing the inputs and outputs to make the trophic efficiencies realistic. ECOPATH can be useful for examining the relative effect of the fishery and predators on sardine. Also, the parameter estimation process provides insight into the relative importance of different parameters to biomass balance. One suggestion, by Julia Parrish, was to use energy in addition to biomass flow, to get a different perspective on trophic dynamics. ECOPATH's limitations are that it has no dynamics (i.e., it has no temporal component) no spatial component and no age or size distribution information.

We discussed alternative modeling approaches that might address other questions. We agreed that a model framework should be chosen based on the question of interest. We decided that a seminal question for sardine is what factors are most important in the expansion and contraction of sardine populations (also the north to south shift in the sardine spatial distribution). We considered individual based and process models as options to address this question.

To focus energy and participants on amassing information and developing a model to investigate the relative importance of factors cited above to sardine expansion/contraction Bob Francis suggested we propose a National Center for Ecological Analysis and Synthesis (NCEAS) working group. Academic and agency scientist from Mexico, California, Oregon, Washington, and Canada all expressed interest in working in such a group. The group focus would be development of an IBM model framework, including rules for feeding and migration (i.e., the Parrish model) as a function of size/age, temperature-defined range of spawning areas, diet and prey selection, juvenile condition and migration, energetics component with growth, fecundity, condition and decision rules for gonad development. Oceanographic conditions will be included through movement of major fronts as barriers to migration, upwelling as a source of food, regime influence on temperature and currents, the role of El Niño in its effect on temperature and currents. A great deal of information must be synthesized, including Oceanographic, energetics, migration, and life-history information and predator feeding, diet and distribution.

Data Availability and Missing Data

We listed available data, with an eye to addressing questions of sardine expansion-contraction and trophic role (e.g. effect on prey, effect on predator diets and feeding rates). Available data sets:

1. **CALCOFI** – Physical data, sardine eggs and larvae, plankton (physical data soon on CDROM);

2. **Newport line (Bill Peterson)** – only 1970's and mid 1990's to present provides sardine and zooplankton density and distribution;

3. **Mexican data** – age and growth data (1990's from Magdalena Bay); also sardine eggs and larvae from incidental cruises along Pacific Coast and Gulf of California; over the last 3 years these data extend to the N. Baja California outer coast (eggs and larvae (~25 cruises both west coast and Gulf of California). Descriptive diet data (one cruise); Ensenada diet data (it was suggested that these data might have problems);

4. **Morphometry data** – shows 2 length-based switches in sardine morphology (28 mm & 150 mm standard length) – unpublished (in a thesis);

5. **Triennial survey data** – National Marine Fisheries Service bottom trawl and acoustic surveys give fish abundance distribution, since 1977. In 1998 an egg pump was deployed to sample the distribution of sardine eggs;

6. **Purse seine data (Bill Pearcy)-** 1979-1985 – mostly gives salmon distribution. These data can show what the system looked like without sardines;

7. **BPA study** – A current study conducted by National Marine Fisheries Service scientists near the mouth of the Columbia river and its environs can provide information of sardine eggs and larvae, and diets or sardines and sardine fish predators (1998+);

8. **GLOBEC** – The U.S. GLOBEC (Global Ecosystems) project has monitored 5 transects since 1998. These provide Oceanography and zooplankton data. They will also have fish sampling from 2000-2002;

9. **Canadian data** – 1960's and 1970's midwater trawl for herring can provide information on the environment without sardine. Triennial midwater trawl and acoustic surveys 1977+, annual midwater trawl and acoustics 1986+. Annual larval trawl surveys, neuston ('82-89,92,93), plankton (annually and all seasons (1985+) sporadic before that. Water samples for phytoplankton species composition 1970s+ along West Vancouver Island – being worked up for 1980's. Surface trawls all seasons 1996+ focussing on salmon and sardines (high-speed midwater trawls);

10. **Mark Lowry** – CA sea lion scat data 1981+ can provide some indication of changes in diet and importance of sardine in diets;

11. **Bob DeLong** - Ca Sea lion and fur seal scat data scattered through 1980's;

12. **Indian midden data** – channel Islands and Alaska can provide some information on the periodic abundance and distribution of sardine as available to an artisinal fishery;

13. **Genetic data** – Hedgecock, CALCOFI reports Mexico and S. Calif. only. NOT micro-satellite study;
14. **Tagging studies** – 1930's and 1940's provides information on sardine abundance and migration during the last period of abundance;

15. **Tuna bait boats catch (Observer and logbook reports)** – Sanchez Rodriguez – provides an excellent, continuous time record of small pelagic fish (e.g. sardine and anchovy) distribution and abundance from California to Southern Mexico.

Spin-off projects considered (with relevant data sources from above)

1. IBM model development – In addition to the NCEAS workshops (recommended below) additional funding is needed to allow a modeling effort to proceed, since resources will be needed for model development

2. Comparison to other Pacific sardine systems – life history comparison, morphometric comparison, migration comparison, synchronicity of abundance cycles.

3. Analysis of juvenile sardine size and condition data – data to be obtained from the tuna bait fish fishery and other ships of opportunity. Little is currently known about sardine juveniles because they are not fished (except for the bait fish fishery). This study could establish a baseline and juvenile condition could be a precursor for expansion or contraction of the population.[3,6,15]

4. Analysis of diet, size at age and condition index data from surveys of opportunity. This study would involve processing sardine data obtained from recent and ongoing BPA surveys, NMFS groundfish surveys and acoustic surveys. Stable isotope analysis could be done on historic sardine data to indicate in general what they are eating (diet trophic structure).[3,5,8,9,14]

5. Comparison of forage quality and size range of sardine with other forage fish. This study would be useful in examining possible shifts in bird and marine mammal diets with the advent or decline of sardine and could help to predict possible condition changes in these upper trophic predators.[3,5,6,7,9]

6. Multi-satellite genetic comparison of sardines in N and S. Is the northern stock derived from the southern (Mexican) stock or from residual populations in California? Hedgecock did a similar study w. electrophoresis, and there already may be a micro-satellite study done (1998). What did it show? All one stock? If possible this study could compare with genetics of sardine stocks in the 1940's and with other Pacific sardine stocks [13]

Table relating possible research projects suggested to available data sources:

Research Project → Data Source	A – IBM Model	B – inter regional comparison	C – juvenile sardine size & condition	D adult diet, size and condition	E – forage quality size comparison	F – Multi-satellite stock comparison
1 CALCOFI	x					
2 Newport line	x					
3 Mexican	x		x	x	x	
4 Morphometric		x				
5 NMFS triennial	x			x	x	
6 Purse Seine			x		x	
7 BPA egg-larvae	x				x	
8 GLOBEC	x			x		
9 Canadian	x	x		x	x	
10 CA SL scat	x					
11 mar mammal	x					
12 Indian middens		x				
13 Genetic data		x				x
14 tagging				x		
15 tuna bait-fish	x	x	x			

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