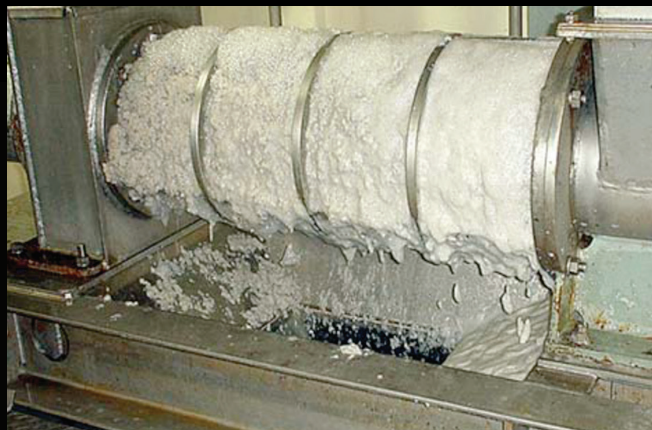


SURIMI *and* SURIMI SEAFOOD

THIRD EDITION



EDITED BY **JAE W. PARK**



CRC Press
Taylor & Francis Group

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Preface

It has not been like 2000 and 2005, when the first and second editions were prepared and published. Even though my project for the third edition was planned in advance and execution commenced perhaps in 2011, the project has moved at an extremely slow pace. I took my sabbatical leave at Korea University in 2011–2012 with my primary goal “to complete all of the manuscripts for the third edition.” But it did not work out as nicely as I had planned and my projected “third edition” was delayed day after day. It was not like 2000 and 2005 perhaps because I have slowed with age and perhaps because I have tried to include too many things in this third edition.

I feel I have made an extraordinary effort for this book as I attempted to add the most up-to-date information in the science of surimi and surimi seafood. The book, consisting of 23 total chapters, is significantly expanded from the 17 chapters of the second edition. The highlight is that this revised/extended book is coauthored by 63 combined scientists/industry leaders. I tried to make this textbook serve as an encyclopedia for surimi and surimi seafood. Therefore, it has broader content and depth. Highlights include historical reviews of surimi technology and industry, comminution technology and application, coproduct utilization, research and development, and nutrition and health benefits. For the production of surimi seafood products, this edition covers crabsticks, kamaboko/chikuwa/tempura, fish balls, and fish sausage in different chapters.

I am very proud of my former students and visiting scientists who worked with me and put up with my never-ending demands while they were at my laboratory. Three visiting professors and 13 former students participated in this book as coauthors of various chapters. I appreciate their hard work, achievements, and contributions to the book.

Since the first edition in 2000, this book has served as an industry guide for the global surimi and surimi seafood industry as a unique textbook written in English. There have been a few requests for this book to be translated into Russian or Chinese. I look forward to seeing it printed in a different language so that we can speak the same language under the word “surimi.”

Special thanks are extended to my longtime associate Angee Hunt for her never-ending efforts to keep me on the right track and highly productive. Along with Nancy Chamberlain, Angee did excellent proof reading for almost all of the chapters.

Finally, I thank my friend and wife Sony, son Duke, and daughter Caroline for their love, encouragement, and support.

Editor

Dr. Jae W. Park has been a professor at Oregon State University (OSU) since 1992. Before joining OSU, he was the director of Technical Services for SeaFest/JAC Creative Foods, Motley, Minnesota, which is the largest crabstick manufacturer in the United States and currently under Trident Seafoods. Since 1992, he has worked with various surimi manufacturers and surimi seafood manufacturers in various countries in the world as a technical consultant.

Dr. Park was elected as an Institute of Food Technologists (IFT) Fellow in 2007, which is the most prestigious recognition for a food scientist. He has published over 120 refereed journal articles, 33 book chapters, and 2 patents, and has accepted over 100 speaking engagements. Having devoted his entire professional career to fish protein (surimi) research and outstanding outreach in technology transfer, Dr. Jae Park has distinguished himself as an internationally renowned scientist in surimi research, education, and technology transfer.

He has received numerous recognition awards for his accomplishments nationally, regionally, and internationally. His most recent recognition was from *IntraFish*, the largest seafood magazine in the world, listing Dr. Park as one of the 100 most powerful seafood executives in 2012.

His previous two books, *Surimi and Surimi Seafood*, published in 2000 and 2005, are the only surimi books published in English since 1992. Almost all global manufacturers of surimi or surimi seafood use this book as a production and technical guide.

As a mentor, he has trained over 40 graduate and post-graduate students for their MS and PhD degrees. He also hosted 29 international researchers who conducted various research projects as visiting scientists.

Dr. Park founded the OSU Surimi School in 1993 and the Surimi Industry Forum in 2001 and offers the programs annually in Oregon. He also founded Surimi School Asia in 1996, Surimi School Europe in 1999, and Surimi Forum Japan in 2010. Over 5000 people have been trained through his 51 surimi school or forum programs offered globally.

His surimi research was featured at the Smithsonian Institute's FolkLife Festival under the name of OSU Surimi Story during June 27 to July 8, 2012. He demonstrated to over 1000 people at the National Mall in Washington, DC what surimi is and how it is made from our sustainable fisheries.

Detailed activities can be found at <http://surimischool.org/park.html>.

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Section I

Surimi and Fish Proteins

1 Historical Review of Surimi Technology and Market Developments

*Jae W. Park, Hisashi Nozaki, Taneko Suzuki,
and Jean-Luc Beliveau*

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fish sausage. The production of fish sausage started to increase rapidly. However, for good quality surimi production, salt addition to surimi before freezing had a negative effect on product quality due to denaturation of pollock proteins. Thus, they shifted their focus to inhibit frozen denaturation of pollock surimi during frozen storage.

1.2.2 1960–1976

The year 1959 through 1960 is a historically important time when Nishiya et al. [3], at the Hokkaido Fisheries Research Station of Japan, discovered a technique that prevented freeze denaturation of proteins in Alaska pollock muscle. This technique required the addition of low molecular weight carbohydrates, such as sucrose and sorbitol, in the dewatered myofibrillar proteins prior to freezing. The carbohydrates worked to stabilize the actomyosin, which is highly unstable during frozen storage [4,5].

The discovery of sugar or sorbitol as a cryoprotectant revolutionized global surimi production. Frozen surimi properly prepared with cryoprotectants was proven to be a way to extend the gelling properties of surimi. Consequently, the surimi industry in Japan expanded significantly in the 1960s and peaked in 1973–1976.

While the addition of sugar to enhance frozen stability of surimi was scientifically solid, the addition of salt to surimi before freezing did not seem to be reasonable, except as a method to create a different type of surimi (kaen surimi). Kaen surimi, due to its inferior gelling ability, has a uniquely smooth texture and is currently sold as a custom-ordered kamaboko. Salt addition (kaen) enhances protein denaturation, especially when frozen surimi is exposed to ambient temperatures during transportation. Dr. Shimizu and Dr. Ikeuchi of Kyoto University tried to prepare surimi with salt (kaen surimi) in 1959 [1]. Since kaen surimi is prepared by adding salt before freezing, and salt promotes protein denaturation, setting (suwari) can be started before the surimi is completely frozen (Endogenous transglutaminase in fish is active even at 0°C to link two amino acids [lysine and glutamic acid] to form a covalent bond. See details in Chapter 18.). Therefore, Dr. Shimizu and his group suggested about 10% sugar addition to prevent suwari.

The Hokkaido government acquired a patent for frozen surimi technology in 1963 and established the Frozen Fish Flesh Association to promote its patent. In the meantime, the Japanese fishing industry started catching Alaska pollock in the Bering Sea and processing it into surimi that was frozen at sea. This was the beginning of factory trawler's at-sea processing. Major seafood companies like Nippon Suisan and Maruha-Nichiro (formerly Taiyo Suisan) started to manufacture surimi on vessels in 1965 and the surimi industry in Japan started to grow rapidly. Before 1959, the catch of Alaska pollock in Japan was 370,000 MT and the quantity of finished products using pollock was approximately 470,000 MT. But in 1971, Alaska pollock harvests were approximately 3 million MT and the production of various surimi seafood reached approximately 1.1 million MT, which was historically the highest record in Japan.

1.2.3 INVENTION OF CRABSTICK

Crabstick, which is called kanikama (crab-flavored stick), was invented in a flake type by Mr Sugino of Sugiyo Co. in 1973 and in a stick type by Mr Osaki of Osaki Suisan in 1975. The invention of crabstick had a significant impact on the global surimi and surimi seafood industry. Considering surimi was primary for Japan and Japanese for 960 years, crabstick became a corner stone to connect Japan with South Korea, the United States, Europe, South America, SE Asia, and China.

While the proportion of crabstick in Japan is relatively small (60,000–70,000 MT), its production in other countries was 350,000–400,000 MT in 2011. Now, approximately 20–25% of surimi is globally used for the production of crabstick.

1.2.4 1976–2012

US Senator Magnuson’s bill became a law, the Magnuson Act, in 1976 and created a 200-mile exclusive economic zone to prevent any foreign vessels to fish outside this limit (Figure 1.3). This law also created the National Marine Fisheries Services (NMFS), including the North Pacific Fisheries Management Council [6], which is the US governing body of the largest white fish biomass, Alaska pollock. The Magnuson Act of 1976 functioned to promote the US seafood industry by creating three-tiered access to fishery resources: Highest priority to US caught–US processed operations; second priority to US caught–foreign processed operations (joint ventures); third priority to foreign caught–foreign processed operations. With this rule, the fishing and processing of Alaska pollock, as well as other fisheries became Americanized [6]. The combination of Japanese processing ability and American catching capability created the first collaborative opportunity envisioned by the Magnuson Act—the joint venture operation (J/V). The first pollock J/V was in 1977 and the first US–Japan pollock J/V was in 1981 [6]. However, the production of surimi from pollock by Japanese firms started to decrease as the pollock fishery became more Americanized.

In the early 1980s, Japan began globally developing surimi from other species [1] while establishing joint ventures in the United States to secure their domestic demand for surimi. Other resources for surimi were tropical fish, such as threadfin bream and lizardfish in S.E. Asia, and other cold water species, such as hoki and Southern blue whiting in the South Pacific Ocean and South Atlantic Ocean. In 1991–1992, the Japanese surimi industry helped the US surimi industry to start making surimi from Pacific whiting off the Oregon coast.

With the manufacture of frozen surimi following the discovery of cryoprotectants, the production of surimi seafood products in Japan increased significantly from 400,000 MT in 1960 to over 1 million MT in 1973–1976 [7]. Japan, as the largest market of frozen surimi in the world, has experienced a gradual reduction of surimi seafood consumption since 1975. Over 1 million MT of surimi seafood production in 1975 gradually decreased to below 600,000 MT (Figure 1.4). This continuous reduction was possibly affected by two major factors: (1) the young generation in Japan preferred Western style meat-based food; (2) Japanese surimi seafood was extremely high quality; however, as the production/marketing went through a severe price competition, low-quality products became

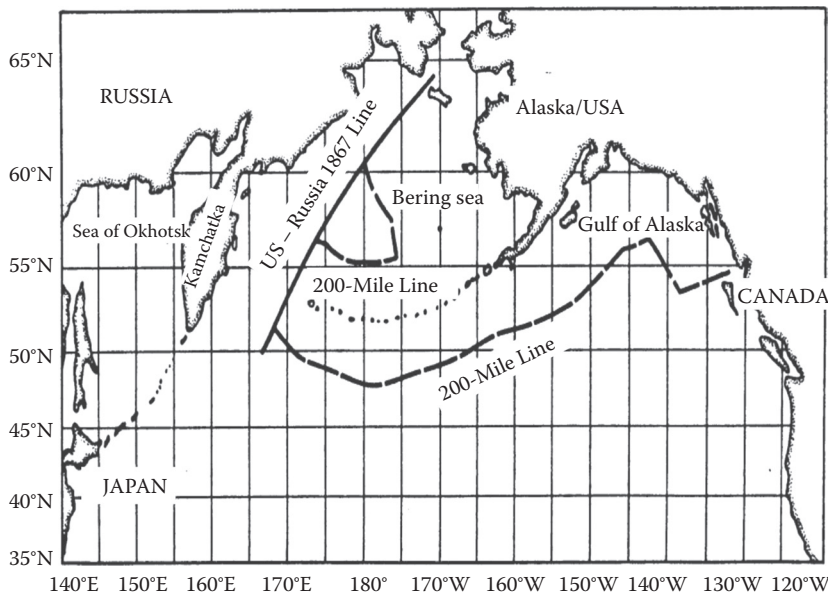


FIGURE 1.3 Fishing ground for Alaska pollock and US fishing territory. (Adapted from R. Draves, *Presented at the 1st Surimi Forum Japan* (July 20–21), Tokyo, Japan, 2010.)

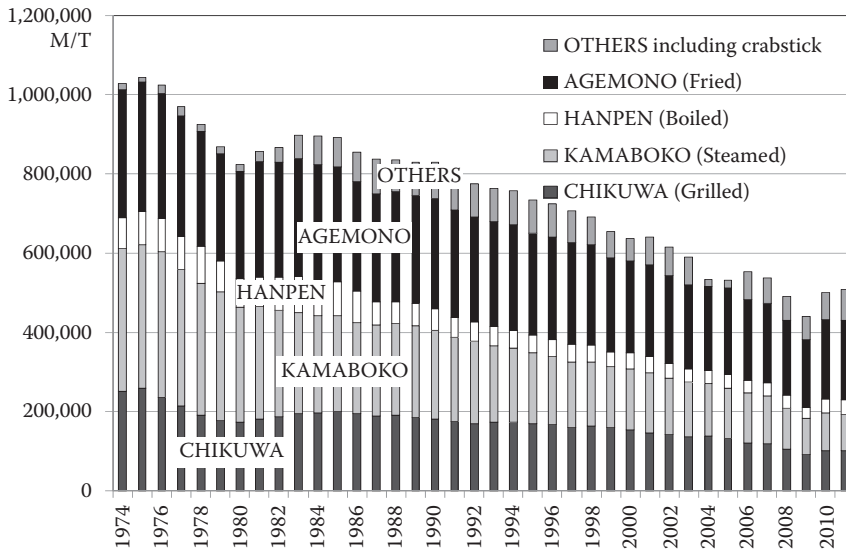


FIGURE 1.4 Consumption trends of various surimi seafood in Japan.

established in the market. As a result, some concerned consumers stayed away from surimi seafood. ZENKAMA (Association of Surimi Seafood Makers) recently made an effort to promote health and nutrition in surimi seafood; however, no significant increase in consumption was reported. The reduction rate, though, has been neutralized in recent years (2008–2011) with consumption at around 500,000 MT.

During the last four decades, the largest reduction in surimi seafood consumption was obtained for steamed kamaboko from 400,000 MT to only 100,000 MT. This was primarily due to the younger generation not eating steamed kamaboko daily like their parents and grandparents. However, the consumption of fried surimi seafood was less effected with a relatively small reduction from 300,000 MT to 200,000 MT. The overall reduction in surimi seafood consumption likely resulted from using low to medium grade surimi instead of high grade pollock surimi (required for premium kamaboko). In addition, the number of kamaboko makers once reached over 3000, but it has been reduced to 946 in Japan in 2011, which has affected kamaboko production.

Various reasons are attributed to the attrition of kamaboko makers. One reason is that it became difficult for small manufacturers to compete against large manufacturers, who have their own distribution and marketing chains nationwide. In addition, since frozen surimi is traded globally, it is affected by global market conditions. In 1991–1992 and 2008–2009, the price of surimi went up extraordinarily high. Consequently, there were a number of kamaboko manufacturers who could not compete due to the high price of surimi and went bankrupt.

History of kamaboko is also explained in detail in Chapter 10 (see Section 10.2.1).

1.3 SURIMI TECHNOLOGY AND INDUSTRY IN UNITED STATES

1.3.1 SURIMI PRODUCTION IN THE UNITED STATES

With the legal justification of the Magnuson Act of 1976, the production of surimi from Alaska pollock in the United States started. Joint ventures grew rapidly despite a variety of difficult obstacles, eventually leading to a bond between fishermen and forming the foundation upon which many of today's business relationships are built [6]. Joint ventures were successful as American fishermen adapted to the needs of the mothership. In fact, with the added catch capability, motherships could refine their operations to maximize profits. As successful as they were, joint ventures only

represented a partial solution to the goal of the Magnuson Act. As American fishermen achieved success in the pollock fishery, various companies visualized additional opportunities.

1.3.2 LEARNED FROM JAPAN

All surimi manufacturing technologies were introduced by Japanese surimi companies. The first US surimi processing plant (Alaska Pacific Seafood, a subsidiary of Marubeni) was built in Kodiak, Alaska in 1984. Two additional plants began making surimi in Dutch Harbor, Alaska, in 1985 (Alyeska Seafoods) and in 1986 (GLS, now UniSea Inc). These three land-based surimi factories opened a new opportunity for American catchers and took a leading role in establishing surimi production in the United States (Figure 1.5). In addition, several investors began making plans to build American factory trawlers and motherships. Numerous vessels started to make surimi from pollock with Japanese technical and production head crews in 1988. This combination of growth eventually led to the elimination of any direct foreign fishing in US waters by 1988 [6].

Pacific whiting (formerly known as hake) surimi production commenced with factory trawlers (1991), primarily off the Oregon coast, and then land-based plants (1992) in Astoria and Newport, Oregon, using Japanese technical assistance. Canada started to build its land-based plants in Ucluelet and Port Alberni, British Columbia, in 1995 (Figure 1.5).

1) US Surimi Manufacturers at Sea				
	Factory Vessels	Start	Parent Company	In 2012
1	American Dynasty	1989	American Seafoods	YES
2	American Triumph	1989	American Seafoods	YES
3	Ocean Rover	1989	American Seafoods	YES
4	Northern Eagle	1988	American Seafoods	YES
5	Northern Jaeger	1990	American Seafoods	YES
6	Seattle Enterprise	1988	Trident Seafoods	YES
7	Kodiak Enterprise	1989	Trident Seafoods	YES
8	Island Enterprise	1989	Trident Seafoods	YES
9	Arctic Storm	1988	Arctic Storm MGT	YES
10	Arctic Fjord	1994	Arctic Storm MGT	YES
11	Alaska Ocean	1988	Glacier Fish	YES
12	Pacific Glacier	1988	Glacier Fish	YES
13	Northern Hawk	1990	Coastal Village	YES
14	Excellence*	1990	Supreme Alaska	YES
15	Ocean Phoenix*	1989	Premier Pacific	YES
16	Northern Glacier	2001	Glacier Fish	Stopped
17	Golden Alaska*	1988	Peter Pan Seafoods	Stopped
18	Arctic Enterprise	1989	Trident Seafoods	Closed
19	American Empress	1988	American Seafoods	Closed
20	Christina Ann	1989	American Seafoods	Closed
21	Arctic King	1989	Arctic King	Closed
22	Morning Star	1989	Morning Star	Closed
23	Endurance	1989	Daerim Fisheries	Closed
24	Northern Victor	2001	Icicle Seafoods	Stopped
25	Bering Trader	1988	Bering Trader Inc	Closed
26	Saga Sea	1988	Emerald Seafoods	Closed
27	Heather Sea	1989	Emerald Seafoods	Closed
28	US Enterprise	1989	Tyson Seafoods	Closed

FIGURE 1.5 US surimi manufacturers.

2) US Surimi Manufacturers at Shore-side including Canada				
		Location	Start	In 2012
Alaska Pollock Surimi				
1	Alaska Pacific Seafood	Kodiak, AK	1984	Stopped
2	Trident Seafoods	Kodiak, AK	1998	YES
3	UniSea	Dutch Harbor, AK	1986	YES
4	Trident (Akutan)	Akutan, AK	1990	YES
5	Trident (Sandpoint)	Sandpoint, AK	1992	YES
6	Western Alaska Fisheries	Kodiak, AK	1988	YES
7	Alyeska Seafoods	Dutch Harbor, AK	1985	YES
8	Westward Seafoods	Dutch Harbor, AK	1991	YES
9	Peter Pan	King Cove, AK	2001	YES
Pacific Whiting Surimi				
10	Pacific Surimi	Warrenton, OR	1995	Stopped
11	Point Adams Packing	Hammond, OR	1992	Stopped
12	Depoe Bay (now Trident)	Newport, OR	1992	YES
13	Inland Quick Freezer	Albany, OR	1992	Closed
14	Crystal Ocean Seafood	Astoria, OR	1997	Closed
15	USP**	Ucluelet, BC	1995	Stopped
16	CSP**	Ucluelet, BC	1995	Closed
17	Port Fish**	Port Alberni, BC	1995	Closed
<p><i>Start:</i> Year when the surimi was first produced. <i>YES:</i> currently produced surimi in March 2013. <i>Closed:</i> Vessel or plant has been closed with no production. <i>Stopped:</i> Vessel or plant has stopped the production of surimi, but it can resume the production any time. * Mothership. ** Canadian operations. Silver hake surimi was also commercially made by Barry Group in Canso, Nova Scotia, Canada (1999–2001).</p>				

FIGURE 1.5 (continued) US surimi manufacturers.

1.3.3 AMERICANIZATION OF SURIMI PRODUCTION

The American Fisheries Act (AFA) of 1998, incorporated in the Omnibus Consolidated and Emergency Supplemental Appropriations Act, 1999 (Public Law 105–277), designated the Maritime Administration as the agency responsible for ensuring compliance with US citizen ownership and control requirements for US-flag fishing industry vessels of 100 ft and greater in registered length. The law eliminated exemptions for vessels that could not meet pre-AFA citizenship standards, phased out of operation many of the largest fishing vessels thought to be destructive to fishery resources, and placed restrictions on the types of entities that hold preferred mortgages on fishing industry vessels of 100 ft or greater. Foreign investment in the fisheries of the United States was limited by AFA, which increased the amount of US citizen ownership [8]. As a result, three mother-ships and 20 catching/processing vessels became eligible for harvesting and processing.

Since 1984, with the first surimi production in the United States, a total of 17 land-based surimi plants were built and, as of 2012, only nine plants currently produce surimi from either pollock or Pacific whiting in North America. A total of 28 vessels were built or remodeled to produce surimi from pollock and/or Pacific whiting since 1988 and, as of 2012, only 15 vessels remain for surimi production (Figure 1.5).

As US surimi production continued as a global leader, Americans were quick to learn processing technologies. They swiftly moved to improve production yield and surimi quality. The change of production yield was made from 12–15% before 1990, to 15–25% by 2000, and to 25–30% by 2010.

This incredible yield increase was made through the adequate fishery management for pollock and whiting and the industry’s efforts in adapting decanter technology and other mechanical innovations for fish cutting.

Decanter technology was introduced in the mid-1990s and expanded to the entire industry by 2000. Decanter centrifuge is able to collect almost all insoluble particles from surimi wash water. Depending on the quality of recovered meat, it can be added to medium- or low-grade surimi. This recovered meat can also be packed alone as recovery grade surimi.

A new fishery management that made a significant impact to the yield was to shift from “Olympic fishing” to “individual transferrable quota (ITQ).” Using a given quota, fishermen carefully harvested fish that meet the quality and quantity of surimi using their own time control. Processors also paid attention on how to recover more meat from fish and how to use trimmings and backbone meat.

Scalp cutter by American Seafoods and Toyo V-cutter by UniSea also made a significant contribution to yield improvement. It is interesting to review the change of fish portions that enter the deboning machine. It has evolved from skinless fillets to skin-on fillets and then to butterfly-shaped H&G fish.

After approximately 30 years of surimi production in the United States, it is feasible that surimi production yield can exceed 30%. The yield increase from 12% to over 30% over the last 30 years has made a significant contribution to keeping our Alaska pollock and Pacific whiting healthy and sustainable. The efforts made by the US government and industry must be recognized for maintaining Alaska pollock and Pacific whiting as the most sustainable fisheries in the world.

1.3.4 US PRODUCTION OF CRABSTICK AS SURIMI SEAFOOD

The invention of crabstick in Japan in 1973–1975 became a corner stone for the globalization of surimi. The United States was the first country outside Japan to manufacture crabsticks. The first US crabstick plant JAC Creative Foods (Los Angeles, CA) was established by Frank Kawana and produced crabsticks in October 1981. At the same time the Berelson Company imported its famous brand Sea Leg from Sugiyo Japan. Consumption of surimi crabsticks reached over 5 million pounds in 1981 (Figure 1.6). All imported crabstick was 3-inch sticks individually wrapped in a film.

As shown in Figure 1.6, the consumption of crabstick increased from 30 million pounds to 75 million pounds in 1983–1984. Since crabstick was primarily used for crabstick salad, the Berelson Company introduced crab flakes instead of stick. This small modification of crabstick into user

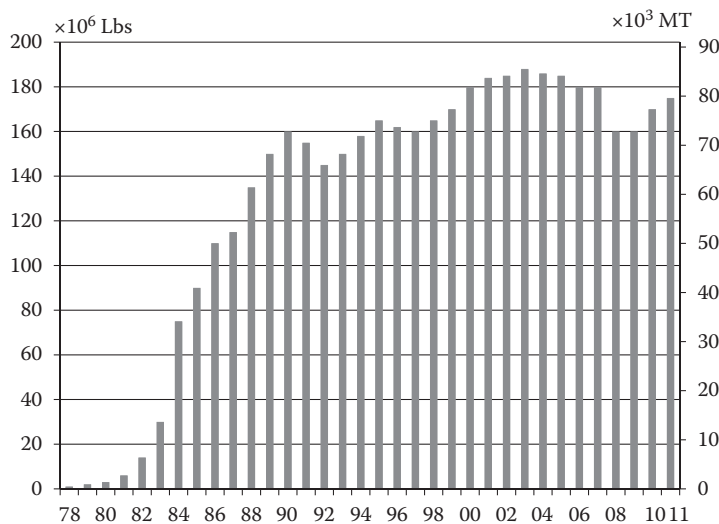


FIGURE 1.6 US surimi seafood consumption (1978–2011).

friendly cuts and flakes resulted in a big jump in consumption. Consumption continued to grow as 11 different plants started to make crabstick in 1984–1986 and reached 160 million pounds in 1990. After the rapid growth, during 1990–2007, the market matured and showed slow growth. Due to the surimi crisis in 1991–1992 and 2007–2008, production/consumption significantly reduced. The current US market in 2012–2013 would be near 200 million pounds, including approximately 20 million pounds of imports.

Mr Kawana's JAC Creative Foods played a major role as a surimi ambassador to teach three major American companies (SeaFest, Louis Kemp, and Icicle Seafoods) how to make crabstick products. Since 1981, a total of 21 different processing plants were built in North America. Through various acquisitions and relocations, by 2012 there were only eight production plants remaining in North America (Figure 1.7) with a market size of over 180 million pounds. It must be recognized that Mr Loren Morey, a founder of SeaFest Products, established his dream plant in a small city (Motley, MN) in 1985. He played a pioneering role in developing a new market with his entrepreneurial business philosophy "Whatever it takes." His dream plant, which encompasses over 110,000 square feet, was later consolidated from seven different processing plants with various mergers and acquisitions. It is currently owned by Trident Seafoods and is the largest crabstick plant in the world.

As for product distribution in the market, more than 90% is flake type, 5% stick type, and the rest is either shreds or molded shrimp. The majority (85–90%), whether the product is flake, stick, or shreds, is used for salad making. The remaining 10–15% is used in the production of California rolls, which are the most commonly consumed surimi seafood in Japanese restaurants in the United States. These two different product applications have controlled US production and market.

The industry has reduced surimi content from 60% to 65% in 1992 to the current level of 25–40%. Consequently, the sensory quality of crabstick has been significantly reduced. However, the product market has remained steady even though there have been variations due to other ingredients used in seafood salad (celery, mayonnaise, lemon) and California roll (cucumber, mayonnaise, steamed rice). These other ingredients have helped camouflage the soft texture of crabstick made with reduced surimi content.

One of the drawbacks to the surimi seafood industry has been that the US government insisted that manufacturers label crabstick as "imitation crabmeat." Although the majority of consumers accept imitation crabmeat as it is, some consumers are concerned that being called "imitation" could be viewed negatively as artificial or inferior. National Fisheries Institute's surimi committee has been working actively with FDA and the industry to develop a positive solution. Their efforts lead to FDA approval in November 2006 of surimi seafood products having a statement of identity: "Crab-flavored surimi seafood, made with surimi, a fully cooked fish protein."

The US surimi seafood industry needs to lead its consumers to try premium crabstick as a snack, seafood pasta with premium texture, and fried surimi seafood. Seafood pasta should be promoted as having high protein and being gluten-free. Fried surimi seafood can be marketed as a healthy food as it gives just 2% total fat while providing the same good taste of typical fried food (10–20% fat).

1.3.5 TECHNICAL INNOVATIONS

Japan and South Korea never produced frozen crabsticks. Since they made chilled products and froze them before shipment, all imported surimi seafood showed significant wetness when the product was thawed and used for salads. This resulted in negative issues in salad processing where crab flakes, mayonnaise, celery, and lemon were used. The exudates diluted mayonnaise and made the salad look less attractive.

US manufacturers, however, made both chilled and frozen products. For frozen crabsticks, they started to use modified starch to reduce the level of product wetness upon thawing. This was a great approach to stabilize crabsticks during extended frozen storage in excess of 1–2 years.

Another technical/operational innovation made by US manufacturers was color co-extrusion on the crabstick. Red-colored surimi paste was thinly applied on the bundled rope before wrapping

	Company	Start	Year, Merged/Sold			Currently Active, or Closed
1	JAC Creative Foods (LA, CA)	1981	1989	SeaFest//AC Creative Foods (Motlely, MN)	1995, Tyson Seafoods; 1999, Bumble Bee Seafoods; 2000, Consolidated in Motley;	Trident Seafoods (Motlely, MN)
2	JAC Creative Foods (Toronto)	1985	1990			
3	SeaFest Products (Motlely, MN)	1985	1989			
4	Louis Kemp Seafoods (Duluth, MN)	1985	1989, Consolidated in Duluth	1992, Tyson Seafoods (Duluth, MN)	2001, ConAgra Foods; 2006, Trident Seafoods	
5	Calista Corp (Olympia, WA)	1986				
6	Nichirei Foods America (Fife, WA)	1990	1997, Trident Seafoods (Fife, WA)		2006, Consolidated in Motley	
7	Icticle Seafoods (Bellingham, WA)	1985	2010, Consolidated in Motley as Trident Seafoods			
8	Trans Ocean Products (Bellingham, WA)	1985	2008, Consolidated in Bellingham			Trans Ocean Products (Bellingham, WA)
9	Kyotaru Oregon (Salem, OR)	1991	2000, Trans Ocean Products (Salem)			
10	Shining Ocean (Seattle, WA)	1985	2003, Relocated to Sumner, WA			Shining Ocean
11	UniSea Foods (Redmond, WA)	1985	1996, Consolidated in Redmond as Fishing			King & Prince Seafood (Redmond, WA)
12	Fishing (LA, CA)	1986				
13	Sugiyu USA (Anacortes, WA)	1987				Sugiyu USA
14	Aquamar (Rancho Cucamonga, CA)	1992				Aquamar
15	LM Foods (Carteret, NJ)	1996				LM Foods
16	Ocean Food (Toronto, OT, Canada)	2000				Ocean Food
17	Seafood Ho (Clareville, NE, Canada)	1985	1997, Barry Group			2003, Closed
18	Kibun USA (Raleigh, NC)	1984	1993, HFI			1994, Closed
19	Kibun USA (Redmond, WA)	1984	1993, HFI			2002, Closed
20	Sea Blends (Seattle, WA)	1986				2004, Closed
21	Ono Fish Cakes (LA, CA)	1987	1991, Yamasa Fish Cakes (LA, CA).			1991, Closed

FIGURE 1.7 Establishment of the crabstick plants in North America.

and cutting into 3 or 5 inch sticks or 1–3 inches for flake production. In 1989 SeaFest/JAC Creative Foods (Motley, MN) started to co-extrude color paste at the same time when the surimi seafood paste was extruded as a thin sheet on the cooking belt (R. Thiede, personal communication, 2012). This co-extrusion color application without wrapping film shortened production time, resulting in improved productivity and eliminated color flaking. This unpatented technology made a significant contribution to simplify crabstick processing in the United States and Europe.

1.3.6 SURIMI RESEARCH AND EDUCATION

Modern surimi technology and science were explored by various scientists in Japan since 1960s. As surimi technology and production moved to Western countries, adequate training and education were highly needed. The United States took a leading role in training and educating the surimi and surimi seafood industry.

Alaska Fisheries Development Foundation performed a significant amount of work and played a great role in developing the US surimi industry in the early 1980s [6]. NMFS/Sea Grant promoted surimi production research and technology through various Sea Grant universities in the 1980s and 1990s. Dr. Tyre Lanier (North Carolina State University), Dr. Chong M. Lee (University of Rhode Island), Dr. Herbert Hultin (University of Massachusetts), Dr. Eunice Li-Chan (University of British Columbia), Dr. Jerry Babbitt (NOAA), and Dr. Jae W Park (Oregon State University) often jointly or independently conducted various surimi and surimi seafood researches to help the US industry advance.

Various surimi conferences were organized in the United States and made significant contributions to enhance US technology and public awareness of surimi and surimi seafood. Dr. Lanier organized various surimi conferences in Raleigh, North Carolina: “Mechanical Recovery and Utilization of Fish” in 1980; two surimi meetings on surimi testing in 1985 and 1986; National Technical Conference on “Fatty Fish Utilization-Upgrading from Feed to Food” in 1987. In 1985, National Fisheries Institute/Roy Martin organized a conference entitled “Engineered Seafood including Surimi.” In 1990, there was a joint surimi conference between the United States and Japan held during the Pacific Chem Society meeting in Honolulu. In 1991, Oregon State University hosted a surimi quality testing workshop in Astoria. John Peter/Dr. George Pigott of the University of Washington organized various 1-day surimi seminars in Seattle late in the 1980s and early 1990s before the establishment of the OSU Surimi School in 1993. Dr. Park organized a conference “New Development in Surimi and Surimi Seafood” during the 10th World Congress of Food Science and Technology in Seoul, South Korea in 2001.

As Dr. Jae Park moved from the crabstick industry to Oregon State University in 1992, he realized the need for a training and education program that could build a partnership between two parties: industry and academia. The first OSU Surimi School (Astoria, OR) was founded in 1993 and is offered every year. He also founded the first Surimi School Asia (Bangkok) in 1996 with the collaboration of the Thai Dept of Fisheries and the first Surimi School Europe (Paris) in 1999 with the collaboration of Activ International and ENSIA. These international schools are offered in alternative years, with Surimi School Asia being offered in even-numbered years and Surimi School Europe being offered in odd-numbered years. The US Surimi Industry Forum was founded in 2001 and is offered immediately before the OSU Surimi School. The first Surimi Forum Japan was offered in 2010 and the first Surimi School South America was held in Peru in 2004. Dr. Park has completed training and educations for over 5000 surimi school graduates since 1993.

As for the technology books covering surimi technology, the books written in English were: *Surimi* by Sunee Sonu (1986), *Surimi Technology* by Tyre Lanier and Chong Lee (1992), *Surimi and Surimi Seafood* by Jae Park (2000, 2005, and 2013). All these books have provided the most up-to-date science and application technology to the global surimi industry at their respective dates of publication.

1.4 SURIMI TECHNOLOGY AND INDUSTRY IN SOUTH KOREA

1.4.1 EARLY DEVELOPMENT

According to Kim [9], Saengsun Sookpyeun, the first surimi seafood-like product was described in a book *Jinyeun Euigwe* published in 1719 (King Sookjong's era). The paste was made with fish mince, soy sauce, starch, sesame oil, and pine nut powder. It was formed, steamed, and sliced before serving. However, this may be slightly different from the current ahmook in South Korea (hereafter Korea). Current ahmook started to be produced commercially in Busan a few years before the end of World War II when Japan withdrew its invasion and control in Korea.

1.4.2 FRIED FISH CAKE AHMOOK

The primary surimi product for Korean people is fried surimi seafood (twighin ahmook). This trend has continued to present day. Even though steamed surimi seafood (tzin ahmook) and grilled surimi seafood (goowoon ahmook) are available in the market, they cover less than 5% market share. Local fisheries poolchi (juvenile ribbon fish) and kangchi (juvenile croaker) were the two primary resources for Korean twighin ahmook. They were often ground as whole fish resulting in a somewhat gritty mouth feel. As fishery resources diminished locally, almost all raw materials are currently imported from Vietnam and China, where low-grade surimi is primarily produced. Busan Ahmook is the unique brand for premium twighin ahmook. The industry controls the quantity of surimi used and additional food safety features are required to use this brand.

1.4.3 CRABSTICK

Korean crabstick is called ghe maht sahl (crab-flavored meat) or maht sahl. The latter is a more popular term. The first commercial crabstick in Korea was produced by Oyang in 1982 and Korea became the third country to make crabstick after the first crabstick development in Japan in 1974–1975 and the production in the United States in 1981. After Oyang, Hansung started its crabstick production in 1983. Then Daerim, Dongwon, Samho, Jinju Ham, Chunil, Samyoung, Namyangsa, and Taehoon started to make crabstick. The primary usage of crabstick is to make gihm bahp (Korean style California roll); therefore, it is a rather long stick that is 18 cm in length.

As the crabstick was used primarily as an ingredient for gihm bahp, where cucumber, radish, and steamed rice camouflaged the soft texture of crabstick, the quality of crabstick in the Korean market reduced significantly and the market suffered. In 2001, Hansung Enterprise introduced a premium crabstick Crami as a snack type (10 cm long) with its intention to increase consumer appeal. This premium crabstick was made with higher surimi content, which used 50% more surimi than low-quality crabstick. They also used a different texture alignment and skin-pack packaging. This premium crabstick was well received by consumers and Hansung now leads the premium crabstick market.

1.4.4 MARKET DEVELOPMENT

The Korean market changed as raw material supplies diminished. CJ Foods took over Samho and changed the company name to CJ Seafoods. Meanwhile, Sajo took over Daerim and Oyang and became the largest player in the crabstick market.

Korea uses approximately 110,000–115,000 MT surimi annually to cover two distinctively different markets (ahmook and crabstick) with its market size of \$175 million and \$135 million, respectively. Korea started to export crabstick immediately after its first production in 1982, primarily to the United States and later to Europe and Russia. Its export reached 47,000 MT in 1997, but has decreased since then. Currently approximately 3000 MT are exported.

1.5 SURIMI TECHNOLOGY AND INDUSTRY IN EUROPE AND RUSSIA

It is known that a Dutch trader, Affish, introduced the first crabstick in Europe in 1979. French and Spanish markets were historically in favor of seafood consumption. Consumers like fresh fishery products, including fish terrine. But all these fresh fishery products last only 4–5 days in the refrigerator. They also encountered difficulties in handling strong fish odor and preparation. In the early 1980s frozen high-quality crabstick was imported from Japan and introduced to French consumers. They were fascinated with the nature of crabstick (convenience, safety, ready to eat, good taste, and no fish odor). At first it was marketed as imitation crabmeat; however, major French companies started to study how to make crabstick in France and created new products. Suddenly the label “imitation” disappeared, and a new name surimi stick or crabstick started to take a strong position in the market.

As the development of crabstick in Japan in 1973–1975 became a corner stone in globalizing surimi seafood, the first two commercial crabstick plants (Cuisimer in France and Kibun in United Kingdom) in Western Europe were established in 1986. At this time, all production technology and equipment were brought from Japan. The primary cooking machine was a conventional line with a 12 m long cooking belt and around 1995, a newly condensed drum cooker with only 4 m cooking area was introduced by a Japanese equipment manufacturer.

For the last 25 years, 33 crabstick plants were built in Europe and Russia (Table 1.1) and consumption reached 230,000 MT in 2011. The surimi seafood consumption increased rapidly at a 15% annual rate for the first 15 years. Between 1985 and 1997, the Western European market, led by France and Spain, switched from frozen imports from Asia to chilled products produced locally. In 2011, the Western market reached 135,000 MT and Eastern Europe more than 100,000 MT. A leading producer is Viciunai with three production plants in Lithuania, Russia, and Spain, and it may be the largest crabstick manufacturer in the world. French companies (Fleury Michon and Alliance Oceane) and Spanish companies (Angulas-Aguinaga and Pescanova) are also leaders in Europe.

As for the production of surimi, there was a minimum effort in producing surimi from Northern blue whiting (NBW) and other local fish. Scoma (France) started its surimi production from sardines, horse mackerel, or pout whiting in 1989, but stopped in 1991. The Joseph Roty II (France), the first European factory trawler, started surimi production in 1989 and currently continues to produce surimi, primarily from Northern blue whiting, as a primary surimi manufacturer in Europe. In 1999, F/T Naeraberg (formerly American Empress) began surimi production of NBW (Faeroe Islands), but in 2006 it was replaced by F/T Antarctic Navigator (formerly American Monarch) operated by pf JFK & pf Naeraberg (Aker). In 2007, F/T Antarctic Navigator stopped surimi operation due to a significantly reduced quota.

There were a few companies involved in making surimi in Russia. Sortavala Fish (St. Petersburg) engaged in surimi production using frozen NBW in 2003 and crabstick production in the same year. Vityaz-Avto in the southernmost tip of Kamchatka Island started to make surimi from Alaska pollock in 2007, but stopped in 2011. There are also small processing facilities in the Kuril Islands.

1.5.1 MARKET DEVELOPMENT IN WESTERN EUROPE

The development of the surimi market in Western Europe mostly resulted from the French and Spanish markets. As of 2011, it is generally known to have a market volume of 60,000 MT in France (Figure 1.8), 40,000 MT in Spain, 12,000 MT in UK, and 8,000 MT in Italy and Benelux/Scandinavia, respectively, and 7,000 MT in Germany.

As the French introduced chilled products with 35 days of shelf life stored at 4°C in 1989, frozen imports lost ground. The majority (94%) of the current French surimi seafood market is a chilled product, while Spain has the largest market for frozen products (mostly imports from China, Thailand, and India). The Spanish market, though, changed from 38% (chilled) versus 62% (frozen)

TABLE 1.1
Establishment of Crabstick Manufacturers in Europe and Russia

	Company	Production Year	Country	Year, Transition (Merged/Sold)	Currently Active or Closed (Year)
1	Cuisimer	1986	France	2007 Alliance Oceane	Alliance Oceane
2	Kibun UK	1986	UK		Closed in 1990
3	Surimi France	1987	France	1997 Fleury Michon	
4	Ifafood	1989	France	1997 Fleury Michon	
5	Protimer	1989	France	2007 Alliance Oceane	Alliance Oceane
6	Kibutz Eilon	1990	Israel		Closed 1994
7	Angulas-Aguinaga	1991	Spain		
8	Comaboko	1991	France		
9	Del Mar	1992	Italy		Stopped 1998
10	Fideco	1995	Italy		
11	Narvik	1996	France		Stopped 2005
12	Maheso	1996	Spain		
13	Pescanova	1998	Spain		
14	Multi-prosur	1998	Spain	2011 Viciunai	Sistemas Britor (Viciunai Spain)
15	Captaine Cook	2000	France		
16	ROK-1	1981	Russia		
17	Makril-Tallinin	1985	Estonia	Viciunai 2004	Closed 2005
18	Zavod Protein	1986	Murmansk		
19	Kven	1986	Russia		
20	Meridian	1986	Russia		
21	Morskoy Zamok	1999	Russia		
22	Kriskal	1995	Estonia		
23	Viciunai	1998	Lithuania		Viciunai (Lithuania)
24	Viciunai	2002	Russia		Viciunai (Russia)
25	Vodnyj Mir	2001	Ukraine		
26	Atlantikstars	2002	Latvia		
27	Albatros	2003	Russia		
28	Norvelita	2004	Lithuania		Stopped 2008
29	Santa Bremor	2004	Belarus		
30	Sortavala	2004	Russia		
31	Pagoto	2006	Ukraine		Stopped 2010
32	Lucky Union	2008	Poland		Lucky Union Foods Europe
33	Russian Fish	2011	Russia		

in 2005 to 53% (chilled) versus 47% (frozen) in 2010. During the last 4 years, frozen surimi seafood imported from India significantly increased in Spain.

As in the United States, the crabstick recipe changed in 1991–1992 due to the surimi crisis in 1991. The surimi content decreased from 55–60% to 40% and the grade of surimi was also downgraded from AA to A or KA. Other species were also blended with Alaska pollock surimi, and food grade proteins, such as milk, soy, or egg white, were added as well.

One of the reasons for the success of the surimi seafood business in France was the establishment of industry-driven quality assurance. In 1997, ADISUR (Association of the Development of Surimi Industry) was established by French surimi seafood manufacturers and ingredient suppliers. ADISUR proactively enhanced consumer communication to reassure that surimi is made from

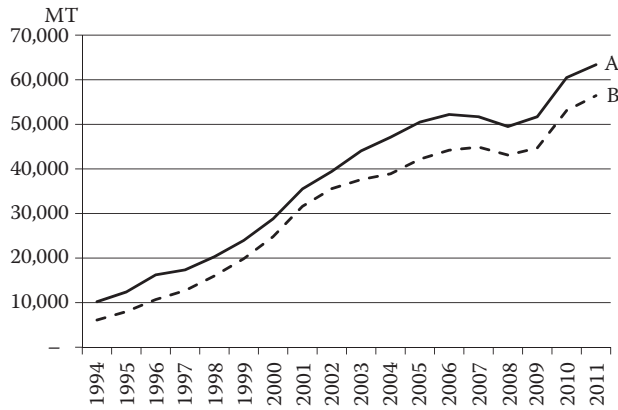


FIGURE 1.8 Consumption (A) and production (B) of crabstick in France. Data provided by ADISUR.

fresh fish fillets and it is a real seafood. It also set its own quality guideline defining that surimi must contain a minimum of 85% fish flesh, and crabstick must be made of a minimum 35% surimi or 30% fish flesh.

Research and development activity in France was the highest among all Western countries that started to make crabsticks. Leading companies in France and Spain developed more than 50 new items during the first 15 years of production. These products included: marinated crabstick in olive oil, baby eel, sausage rolls, molded products for kids, crabstick with cheese or mayonnaise co-extruded, lobster slices, and smoked salmon sticks. The leaders also developed innovative packaging systems. Unlike US consumers, French consumers like to try new or different food products, which contributed to the success of the market development for various crabsticks. Coraya's mini crabstick is one of these successful examples.

During 2004–2009 the market was rather saturated and the growth rate was not significant (Figure 1.8). However, the manufacturers continue to strongly advertise using TV, newspapers, and local communication methods. In 2010, the French market was boosted by 20% after a newspaper article reported on the Dukan Diet. It said surimi seafood is a good and nutritious product for the Dukan diet. In addition, beginning in 2010, the French market has been moving toward more or less “clean label” products with no artificial flavors and no phosphates. However, crabsticks are often made with cheese layered inside to balance taste and texture.

Spain is the second largest market and producer of surimi seafood in Europe. Its market is about 40,000 MT with food service and retail at 40% and 60%, respectively [10]. There are four different product categories: chilled crabstick, frozen crabstick, chilled baby eel, and frozen baby eel at 22%, 51%, 12%, and 15% by volume or 25%, 27%, 28%, and 21% by value, respectively. An obvious trend in recent years is the transition of crabstick from “frozen” to “chilled”: 38%/62% in 2005 to 53%/47% in 2010 [10]. As in France, the proportion of “chilled” crabstick will continue to grow. There are four crabstick manufacturers (Angulas-Aguinaga, Pescanova, Viciunai, and Maheso) and seven angulas (baby eel) manufacturers (Angulas-Aguinaga, Pescanova, Nakulas, Angulas Mayo, El Angulero, Manterola, and Maemiño). Surimi-based Angulas was developed with the assistance of Nichirei Foods (Japan) in the early 1990s and is considered the most popular product after crabstick. This seafood pasta-type product is made primarily with high-grade Alaska pollock surimi and is marketed at a high price.

1.5.2 MARKET DEVELOPMENT IN EASTERN EUROPE AND RUSSIA

While Mr Frank Kawana played a key role in developing the US crabstick industry, Mr Aare Asi was a technical and business ambassador for the development of the surimi and crabstick

industries in the Soviet Union. His numerous efforts in making surimi and crabsticks began with Yanagiya Machinery of Japan and the Soviet Union government as early as 1985. Surimi production trials began using cod (Baltic Sea), Northern blue whiting (Murmansk), and Alaska pollock (Vladivostok) in the late 1980s, but did not last long due to the collapse of the Soviet Union in 1991. There was also a small effort in making surimi from Alaska pollock in Kamchatka between 2008 and 2010.

Crabstick production started out primarily in the western side of Russia (Table 1.1). Five factories (Rok-1, Makril-Tallinin, Zovod Protein, Kven, and Meridian) were established in the 1980s during the era of the Soviet Union. The consumption of crabstick in Eastern Europe, including Russia, has grown significantly from approximately 2000 MT in 1995 to 110,000 MT in 2011. As its market developed with an increased demand, cheap and medium/low-quality crabstick invaded this region. As a result, the price competition damaged the reputation of crabstick from 1995 to 2005. In addition, the Eastern European market was affected by the recent slow economy. In recent years local manufacturers also changed their marketing strategies by switching from frozen crabsticks to chilled products. Viciunai was the first to build a significant market share for chilled products. In 2010, chilled markets represented 5000 MT.

The production of crabstick spread over all of Eastern Europe, including Estonia, Lithuania, and Belarus. Ten more processing plants were established in 2001–2011. This industry started with Chinese and Korean imports. Now, domestic production has begun and covers domestic demand and supplies in parts of Europe as well. The world's largest crabstick manufacturer, Viciunai, leads Eastern Europe and Russia with its multinational factories in Lithuania, Russia, and Spain.

1.6 SURIMI TECHNOLOGY AND INDUSTRY IN SOUTH AMERICA

1.6.1 SURIMI FROM ARGENTINA

In 1989, the Argentine Fishery Dept started to look into a feasibility study on the production of surimi from Southern blue whiting and hoki, particularly from the south of Argentina. Nippon Suisan, with its Argentine subsidiary Pesantar S. A., started surimi production in 1989 using three surimi vessels, named Rikuzen Maru, Kongo, and Yamato. During 1992 and 1993, three other surimi vessels were added to the fleet: Gran Estella from Hansung Enterprise (Korea), Centurion del Atlantico from American Seafoods (currently owned by Aker), and Othori Maru (a joint venture between Kyokuyo of Japan and Harengus of Argentina).

From these six vessels, only two remain in production in 2012: Centurion del Atlantico and Tai An, which replaced Othori Maru after being damaged by fire. Centurion del Atlantico today is managed by Estremar S. A. with Norwegian owners and Tai An is managed by San Arawa S. A. with Argentine and Japanese owners. Southern blue whiting has been the main species caught for surimi. Lately, the percentage of hoki increased due to the reduced number of vessels. Recently, the hoki fishery was awarded with the certification of sustainability by MSC. Both vessels operate from the Southern port of America, Ushuaia, in latitude 55° south, and the main fishing area is between latitude 53 and 55 south, where weather conditions are extreme along with strong currents. Surimi from Southern blue whiting and hoki is primarily sold to Japan.

1.6.2 SURIMI FROM CHILE

The production of surimi from jack mackerel in Chile started due to the reduced production of surimi from atka mackerel in Japan. In 1988, Pesquera Loa Sur, which later became Pesquera San Jose, started to make surimi with Japanese assistance in Coronel. By the beginning of 1992, there were four surimi factories in Chile (Pesquera San Jose, El Golfo, Camanchaca, and Congelados del Pacífico). All surimi was exported to Japan. During the mid-1990s, hake surimi was produced under the Olympic fishing system, where a large volume of fish was processed

quickly and then exported to Europe. In 2001, when the ITQ system was adapted by the Chilean government, hake started to be used for fillets or H&G, resulting in discontinuation of surimi production from hake.

In the meantime, El Golfo started to make jack mackerel surimi for Europe in 2000 using decanters instead of screw presses as a means to dewater the washed meat. The export volume to Europe and Russia reached as much as 2000 MT a year in 2004–2005. Pesquera San Jose also produced jack mackerel surimi during this period. However, jack mackerel surimi production started to decline in 2008. In 2010, the earthquake in Central Chile, together with the drastic reduction of jack mackerel quota and high prices of other fishery products (frozen whole fish, fish meal, or oil), forced the two plants to stop surimi production.

Since 1994, Union Sur, a factory trawler operated by Emdepes/Nippon Suisan, has been producing surimi from hoki and Southern blue whiting in Chile.

1.6.3 SURIMI SEAFOOD FROM SOUTH AMERICA

Surimi crabstick production in South America started in the early 1980s, similar to North America, by Santa Elena in Argentina. Three additional processing factories for crabstick were built in South America: Arteva (Uruguay), which is closed and replaced by Serrana/Megarol in 2013. MGS Foods (Brazil), and Free-Ko (Peru), which is now no longer producing surimi seafood. However, the overall market size has not grown significantly and produces less than 5000 MT a year.

The largest consumption of crabstick and other surimi seafood (Japanese traditional products) is observed in Brazil. MGS Foods, established in 2002, is the largest crabstick manufacturer in South America. The market size of Brazil is approximately 4000 MT of crabstick per year and 500 MT of traditional Japanese surimi seafood. Arteva closed its production in 2011 due to financial problem. It exported 100% with almost zero consumption in the domestic market. A new company, Megarol, resumed crabstick production in Uruguay in 2012. Santa Elena in Argentina also reduced its production recently.

1.7 SURIMI TECHNOLOGY AND INDUSTRY IN SOUTHEAST ASIA AND INDIA

The use of surimi-like materials may have a long history in Southeast Asia, primarily through Chinese descendents. They enjoy various forms of fish ball, which is made using surimi, fish mince, or mince from shrimp or squid. Singapore is the country with the highest consumption of fish ball per capita (~10 kg). China, Taiwan, and Thailand also consume a large volume of various fish balls.

1.7.1 THAILAND

Thailand has led surimi and crabstick production in Southeast Asia with both volume and technology. Various tropical fish are used for surimi production, but threadfin bream, lizardfish, big eye snapper, and goat fish comprise more than 90% of all raw material. As early as 1971, two Japanese companies, Rosa and Mitsui, teamed up with Apitoon Enterprise Industry for possible production of surimi from tropical fish in Thailand. In 1978–1979 the first surimi equipment from Bibun was shipped to Apitoon. It was in 1979 when the first commercial surimi was manufactured in Thailand by Apitoon. However, after Nissui and Apitoon signed the contract to develop surimi in 1980, good quality surimi started to be manufactured in Thailand. Since then, the surimi business has grown year after year, with an increase in the number of surimi manufacturers. The highest surimi production in Thailand (~160,000 MT) was in 2003. With continuous fishing efforts and limited fishing entry to Indonesia, it is now stabilized at 80,000–90,000 MT a year. There were 17 factories in 2007 and 15 in 2011–2012, with half located in Samutsakhon Province [11].

As for surimi seafood production, Thailand produces the most crabstick products in Southeast Asia. A&N Foods is the first company that produced crabstick in Thailand with a business cooperation with Nissui in 1987. There are nine crabstick factories in Thailand with the majority being located in the Samutsakhon Province. There are three different surimi-based product categories in Thailand: crabstick/chikuwa/kamaboko, fish cake/fish ball, and dried fish snack (taro, fisho) with current volumes of 70,000 MT, 18,000 MT, and 4,400 MT, respectively [11]. As Thai consumers start to think of their health and food, the consumption of surimi seafood has increased significantly. Currently 47,000 MT are exported while the rest is consumed domestically.

1.7.2 INDIA

The history of Indian surimi dates back to 1990 when Marine Products Export Development Authority of India introduced the concept of surimi to a few Indian seafood exporters. Based on an invitation from the Government of India, a team from JETRO visited India to ascertain opportunities and, subsequently, to meet interested companies. Hindustan Lever Limited (HLL) was shortlisted thereafter. Most of the other packers did not show any interest in surimi as the conventional seafood export was booming. HLL decided to start this venture in Gujarat with collaboration with Shinto Corporation, Japan, and signed a long-term MOU for technology/sales. The factory was commissioned in late 1994 and commercial production commenced in late 1995. Simultaneously, in 1995, Gadre Marine Exports started surimi operations in Ratnagiri with technical assistance from Daerim (South Korea). Soon, Naik Ice and Cold storage put up a surimi line in Ratnagiri as well. During the same year, Amar Cold Storage in Porbandar started a surimi line using Korean machinery. In 1997 another surimi factory, SK Big Star, was established on the East coast in collaboration with Korean company, but due to the Korean currency debacle, the factory was soon shut down.

During the next few years, HLL first expanded their surimi business in Ratnagiri in addition to Hiravatis factory in Porbandar. Subsequently, HLL sourced three second-hand lines from Japan and set up their own manufacturing factories in Mumbai, Udipi, Kochi, and Kanyakumari in South India. HLL also extended its factory on the East coast of India, thereby accounting for over 60% of India's production/exports of surimi.

After 2002, the conventional seafood business in India encountered troubled times and many packers felt the need to explore new business. With the success of the HLL surimi business, many packers ventured into surimi over the next few years. As of 2012, there were seven surimi factories in Gujarat, five in Mumbai, two in Ratnagiri, one in Goa, one in Udipi, and one in Vizag on the East coast. All, except one factory with decanter technology, use refiner and screw press to dewater washed mince. The total surimi production in 2011 was 58,000 MT and 53,000 MT was exported to various countries.

In 2001, HLL started the production of crabstick/surimi crab claws at the Gujarat factory with a Korean line and soon doubled capacity in 2003 by buying a second Japanese line. They were followed shortly by Gadre Marine Exports who set up a factory in Ratnagiri with 10,000 MT capacity of crabsticks and molded products using Korean machinery. These two existing factories produced around 11,000 MT in 2011. With almost no domestic consumption, the majority was exported to Europe and the United States. In 2013, Gadre Marine took over the surimi and surimi seafood operations of HLL and became the largest surimi manufacturer and only surimi seafood manufacturer in India.

1.7.3 VIETNAM

Vietnam became one of the leading surimi producers in 2010–2012 with an annual surimi production of 100,000–120,000 MT. This was a big increase compared to 40,000 MT in 2005. However,

due to poor harvesting technology, the majority of surimi is medium to low grade. Surimi is often produced with mixed species. Over 40% of surimi production is currently exported to Korea and 15% goes to Japan. Since 2011, Vietnam surimi has been successfully exported to Thailand. There are about 50 surimi factories and four crabstick factories in Vietnam [12]. There is no fishery management to control the fishing season, by-catch, fish size, or species that are harvested.

1.7.4 CHINA

China might have started to produce surimi seafood before Japan. According to the book *Sheng Ji Zong Lu*, the Chinese fish ball is believed to have originated during the Qin dynasty (BC 221–207: Qin Shi Huang, the first emperor of China). However, Chinese literatures first recorded the fish ball in 1111–1118 [13].

Surimi production trials in China were made in 1984–1985 using freshwater fish, but failed [14]. Longsheng Aquatic Products (Yuhuan, Zhejiang) first started to make surimi from marine fish using modern processing technology in 1993. However, production records were not available until recently. It is believed the annual production of surimi is close to 120,000–130,000 MT [15]. China has over 60 manufacturers of surimi from marine fish and they are concentrated in four major areas: Zhejiang, Fujian, Guangdong, and Guangxi Province. In addition, about 13 surimi manufacturers of freshwater fish are located in Hubei Province.

It is also believed that there are over 2000 manufacturers of surimi seafood (fish cake, fish ball, and crabstick). Fish cake is primarily produced in Hubei Province (Central China), fish ball in Southern China (Fujian and Guangzhou Provinces), and crabstick in Shandong and Liaoning Provinces.

During the last 10 years, as China became more industrialized, consumer's interest toward fish and fishery products increased significantly. As shown in Figure 1.9, the production of surimi seafood in all categories increased from 100,000 MT in 2001 to 1 million MT in 2010. This trend should continue in the future.

1.7.5 MALAYSIA AND INDONESIA

These two countries started making surimi from bycatch in the 1990s. Now the industry has expanded with 15 plants in Indonesia and 10 plants in Malaysia [16]. But the total surimi and surimi seafood production volumes are not clearly recorded. Due to the abundance of tropical fisheries for surimi, their role in Southeast Asia will continue to grow.

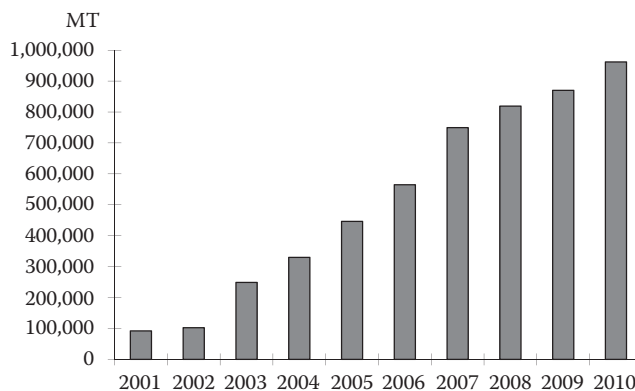


FIGURE 1.9 Production of surimi seafood in China.

1.8 SUMMARY

Surimi technology originated in Japan, and Japan has had a leading global role in developing surimi and surimi seafood. History indicates surimi dates back to approximately 900 years ago. However, modern surimi technology began in 1960 with the discovery of cryoprotectants, which maintain the gelling functionality of fish proteins under relatively long frozen storage. The development of crabstick in Japan 1973–1975 played a major role in globalizing surimi, resulting in the expansion of surimi seafood consumption outside Japan to the United States, Europe, and Russia. Commercial surimi production also changed significantly: (1) from Alaska pollock as a single source to pollock and other species, particularly tropical fish; (2) production yield increased from 12% to 15% in the 1990s to 30% or higher in 2010, which made fishery resources more sustainable.

As for the market development of crabsticks, the quality of crabsticks suffered in certain segments due to reduced surimi content and increased fillers. Assuming it is also a part of market developments, the quality-driven products have recently prevailed in certain countries. As the market share of health conscious consumers increases, the addition of omega-3 oil and removal of chemical ingredients will continue to influence global market trends.

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2 Surimi Resources and Market

Pascal Guennegues and James Ianelli

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2.1 INTRODUCTION

The surimi industry is continuously changing due to the variability of different fish stocks around the world. This variation can arise as a consequence of environmental conditions and/or overfishing, but can also be due to changes in the global economic situation. The demand for alternative fish products can also affect the supply of raw materials for surimi.

Walleye pollock (*Theragra chalcogramma*; also known as “Alaska pollock”) was the first large-scale source of fish to be used for surimi production. It remains the species of reference for surimi production even though today it represents less than one-quarter of world surimi production. Southeast Asia has become the largest fish resource for surimi production, representing 60% of the global surimi production, by utilizing threadfin bream (itoyori), lizard fish (eso), big eye snapper (kintokidai), ribbon fish (tachuio), croaker (guchi), and many other tropical species. The species name within parentheses is Japanese, which is commonly used for production and trading.

New technologies have allowed new resources to be used as raw material for surimi. The use of protease inhibitors, for example, made it possible to use Pacific whiting from the west coast of the United States and Canada for surimi production. Decanter technology and new washing techniques have allowed for processing of surimi from fatty fish, such as jack mackerel. A pH-shift technology has allowed good quality surimi to be processed from giant squid in Peru.

The increasing worldwide demand for frozen fish in various forms, however, has resulted in higher costs for surimi and diverted fish supply from surimi to alternative products (whole round, headed and gutted, fillets, blocks, and mince). In addition, increased fishing costs (related to oil prices) have increased prices for surimi. These trends have forced the surimi seafood industry to learn how to use new species and lower quality surimi (lower functionality, darker color) to process surimi products. More efficient technologies, which allow surimi processors to increase surimi yields using the same amount of fish, have also been explored. Improving the economics of surimi processing has been necessary in order to remain profitable in a highly competitive environment.

The international marketplace for surimi has changed as well. Japanese consumption of surimi seafood has continuously declined during the 1990s and 2000s, as the younger generations have gradually shifted to a more western diet (greater protein intake from other sources, e.g., beef, pork, and chicken) [1]. On the other hand, the market of surimi seafood has developed and grown considerably in the United States, Europe, Russia, Southeast Asia, and China.

Better application of fisheries management principles for sustainable fisheries continues to strengthen conservation measures and attain more optimal yields. Increased emphasis on stock assessment, reduction of fisheries bycatch, and maximum utilization of fish harvests, as well as an increased awareness of ecological issues, continue to improve fishing and utilization practices. The surimi supply has increased from an average 500,000 tons (MT) over the 1990s to 750,000 by 2010. This increase is mostly due to the increased production of tropical fish surimi in Southeast Asia and China. Surimi is now produced from resources that span the globe as shown in Figure 2.1. This chapter will discuss surimi production and fisheries resources used for surimi.

2.2 COLD WATER WHITE FISH USED FOR SURIMI

2.2.1 ALASKA POLLOCK

The pollock fishery, in waters off Alaska, is the largest U.S. fishery by volume. Pollock continues to represent over 40% of the global whitefish production with the market disposition split between fillets, whole (head and gutted), and surimi. Pollock is considered a relatively fast growing and short-lived species and currently represents a major biological component of the Bering Sea ecosystem. Pollock is harvested with fishing vessels towing large pelagic trawl nets.

The pollock fisheries for surimi began in the mid-1960s, after Japanese scientists discovered the function of cryoprotectants in preserving protein functionality for frozen washed fish mince

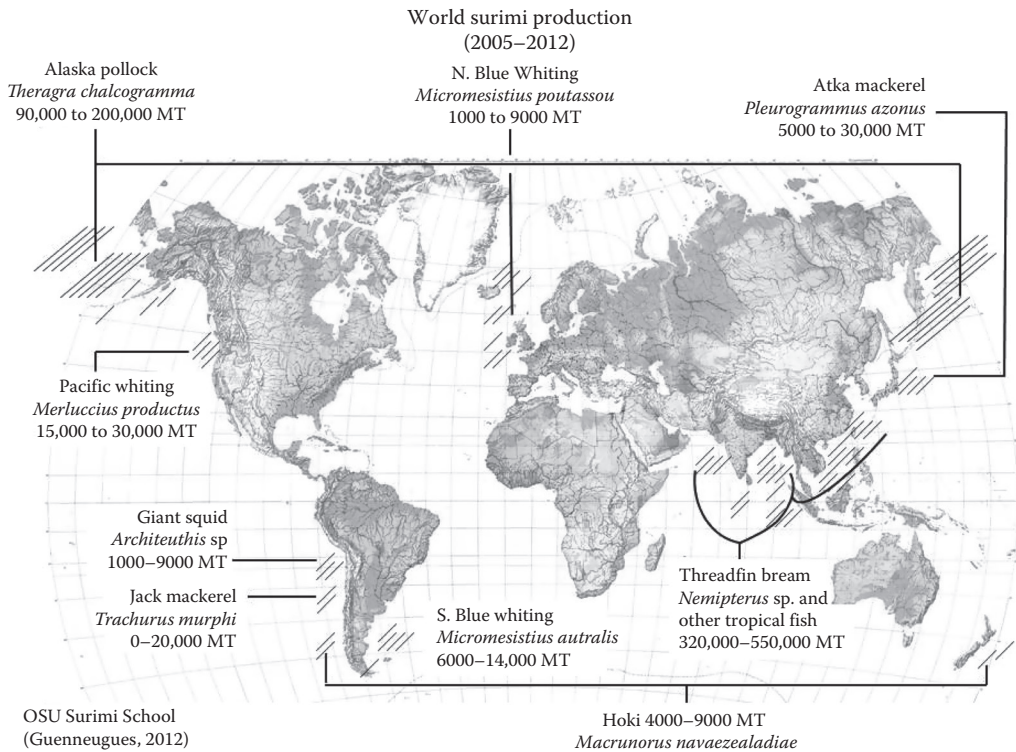


FIGURE 2.1 Geographic locales for world surimi production, 2005–2012.

in 1960. This allowed Japanese vessels to fish at sea for extended periods of time and to harvest, process, and store frozen surimi on the vessels. In addition, the domestic surimi-based seafood industry in Japan was revolutionized, as manufacturers could now receive product year-round [2]. Alaska pollock soon became the resource of choice for the rapidly growing surimi industry. It also became the largest resource for industrial fish fillet blocks that are used by the industry for processing breaded fish and prepared food. Another important component of the commercial production of pollock is the sale of roe from prespawning pollock.

In 1998, the American Fisheries Act (AFA) rationalized the Alaska pollock fishery by identifying the vessels and processors eligible to participate in the Bering Sea pollock fishery. This ended the “race for fish,” which allowed for more efficient operations and improved production. With this change, the four main sectors of the pollock fleet were allocated fixed proportions of the annual pollock total allowable catch (TAC). The sectors include: Inshore catcher vessels, offshore catcher/processors, catcher vessels delivering to motherships, and a special allocation (10%) to the Community Development Quota (CDQ) Program. Shore-side operations are primarily located in Dutch Harbor, Alaska, and factories are also located in Akutan, Kodiak, and Sandpoint. By 1999, there were seven companies producing surimi at these locations, which were close enough to the fishing grounds to allow shore-based vessels to capture pollock and return to offload at plants, usually within 48 hours.

The Bering Sea pollock TAC is further divided into two seasons: A season (January 20 to June 10) and B season (June 10 to November 1). The fleet targets prespawning pollock for their valuable roe in A season, which typically ends in early April. The B season fishery focuses on pollock for fillet and surimi markets. The fleet harvests most of B season TAC during June through early October. The spatial distribution of the fishery also varies between seasons with the winter “A-season” fishery generally

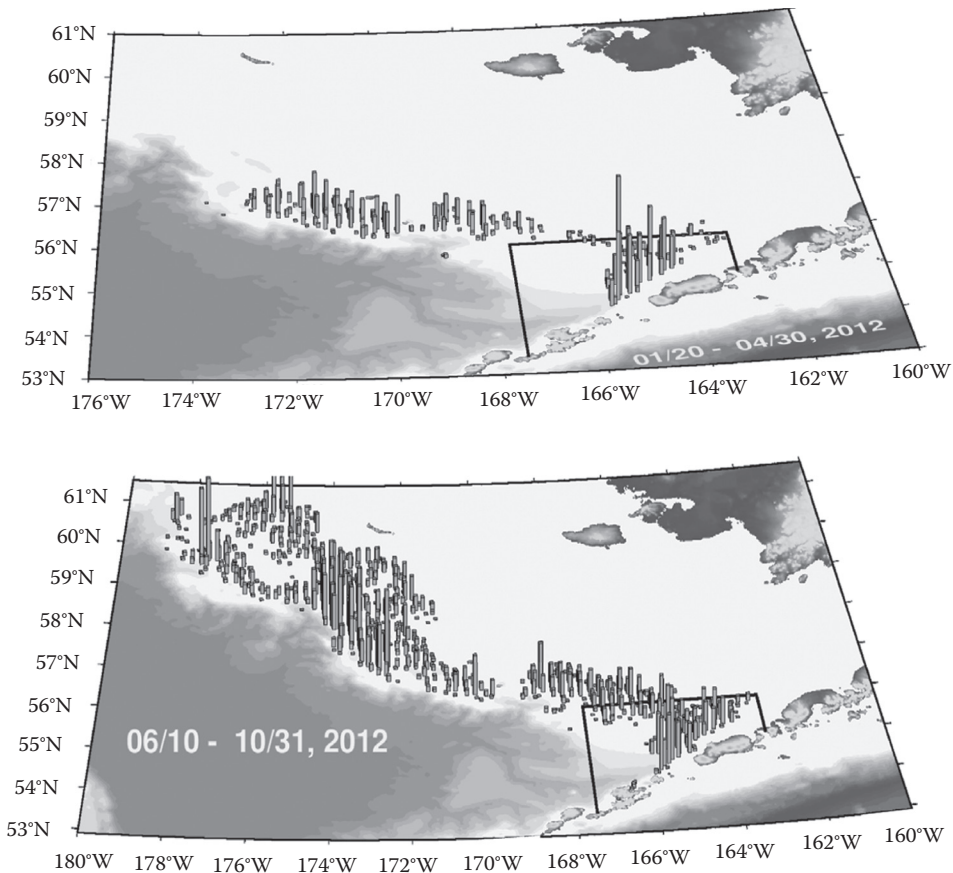


FIGURE 2.2 Alaska pollock 2012 catch distribution during the winter (a) and summer-fall (b). Vertical bars represent the relative magnitude of the catch, black line delineates the “catcher-vessel only area” which is in effect during the B-season. (Adapted from J. N. Ianelli et al. *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1:51–156. 2012.)

constrained by ice and focused in the southeast portion of the Bering Sea, whereas the summer-fall “B-season” fishery is more broadly distributed mainly along the 200 m depth contour (Figure 2.2).

From 1954 to 1963, pollock was harvested at low levels in the Eastern Bering Sea and directed foreign fisheries began in 1964. Catches increased rapidly during the late 1960s and reached a peak in 1970–1975 when they ranged from 1.3 to 1.9 million MT annually. Following a peak catch of 1.9 million MT in 1972, catches were reduced through bilateral agreements with Japan and the USSR. Since the advent of the U.S. Exclusive Economic Zone (EEZ) in 1977, the annual average Eastern Bering Sea pollock catch has been 1.2 million MT and has ranged from 0.9 million MT in 1987 to nearly 1.5 million MT in recent years (Figure 2.3). U.S. vessels began fishing for pollock in 1980 and by 1987 they were able to harvest 99% of the quota. Since 1988, only U.S. vessels have been operating in this fishery and by 1991, the current NMFS observer program for North Pacific groundfish fisheries was in place.

Since the Alaska pollock fishery is so closely monitored (100% observer coverage for all vessels since 2011), the biological sampling programs can reveal interesting features about how the fishery is affected by the variability of year classes within the population. For example, the monthly size compositions of the pollock catch from 2010 to 2012 show the appearance of the 2008 year-class as

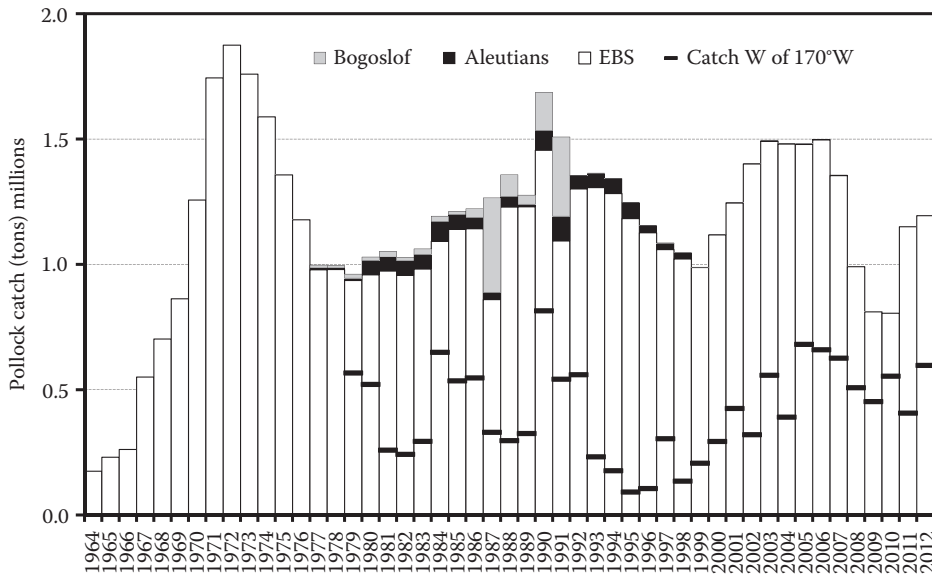


FIGURE 2.3 Alaska pollock catch estimates from the Eastern Bering Sea (EBS), Aleutian Islands, and Bogoslof Island regions, 1964–2012. The 2012 value is based on expected totals for the year. (Adapted from J. N. Ianelli et al. *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/ Aleutian Islands Regions*. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1:51–156. 2012.)

it becomes more prominent (Figure 2.4). The availability of different sizes and age groups affects the mix of product forms that the industry will target (generally smaller pollock results in higher proportions of surimi production).

Bottom trawl surveys are conducted annually and echo-integration trawl surveys every other year. Both occur during summer months and provide a synoptic overview of the relative densities of

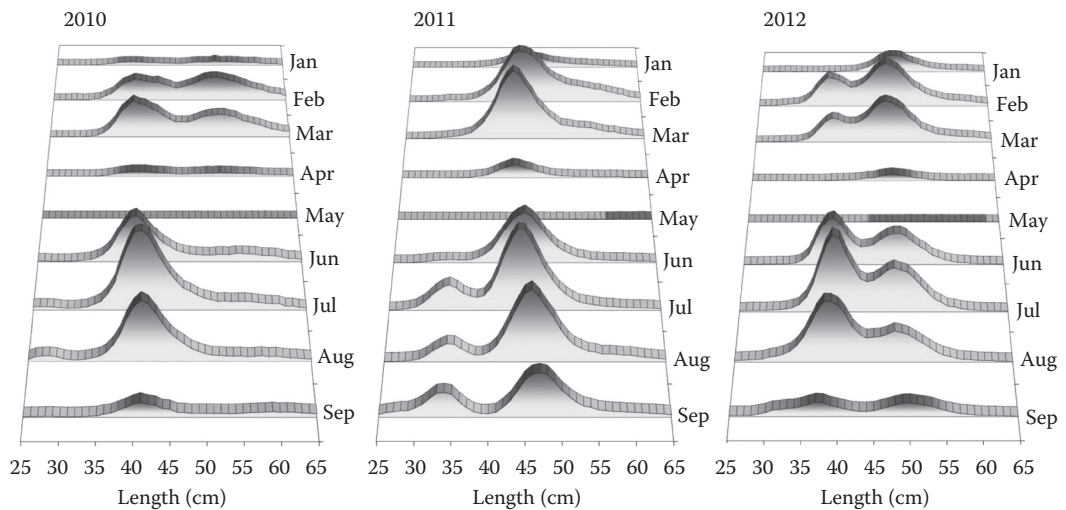


FIGURE 2.4 Monthly data on the length frequency of EBS pollock based on scientific observer data, 2010–2012. (Adapted from J. N. Ianelli et al. *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1:51–156. 2012.)

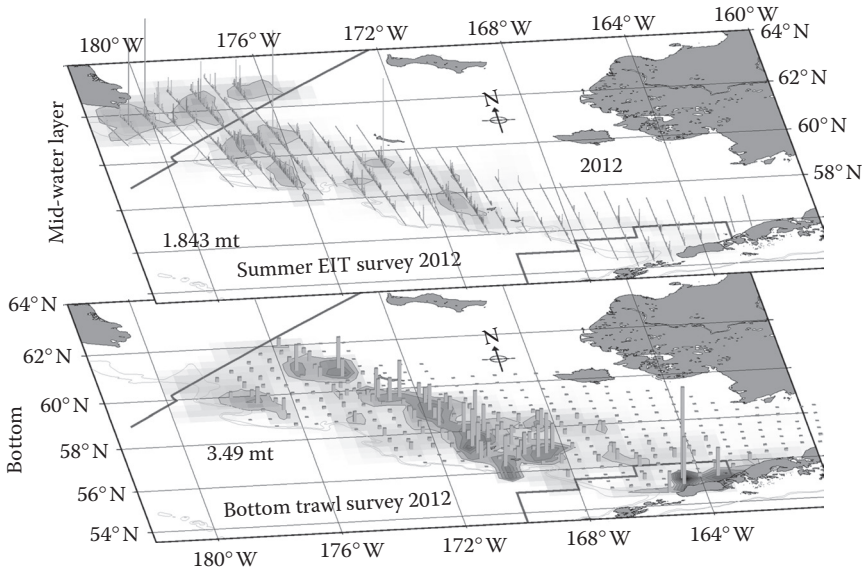


FIGURE 2.5 Acoustic-trawl and bottom trawl survey results for 2012. Vertical lines represent biomass of pollock as observed in the different surveys (mt = millions of t). (Adapted from J. N. Ianelli et al. *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1:51–156. 2012.)

adult and prerecruit pollock (e.g., Figure 2.5). The data are combined with extensive observer samplings and evaluated within a statistical stock assessment model to provide quota recommendations each year. After an extensive review within the North Pacific Fishery Management Council process, the assessments are posted at www.afsc.noaa.gov/REFM/Stocks/assessments.htm.

The most recent assessment [3] shows that the biomass declined sharply between 2005 and 2008 due to a period of below-average recruitment (Figure 2.6), but has subsequently improved and is estimated to be about 22% higher than the target spawning level for 2013 [3] (Figure 2.7). It is

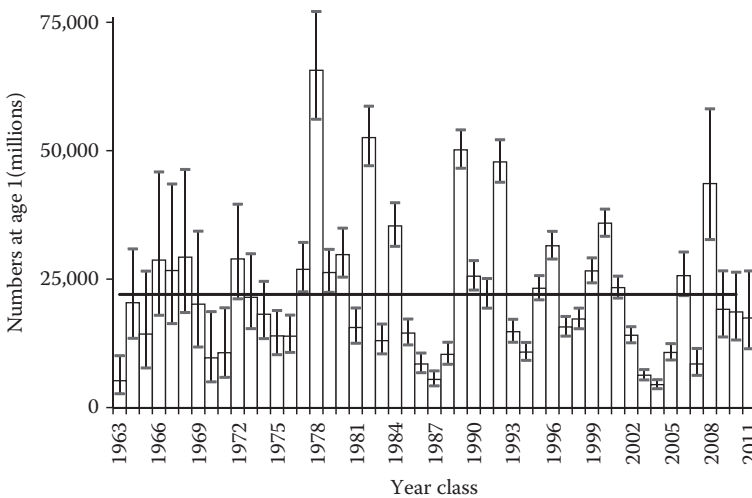


FIGURE 2.6 Eastern Bering Sea pollock estimated year-class strengths (as age-1 recruits). Line represents the mean value and connected dashes represent approximate upper and lower 90th percentile confidence bands.

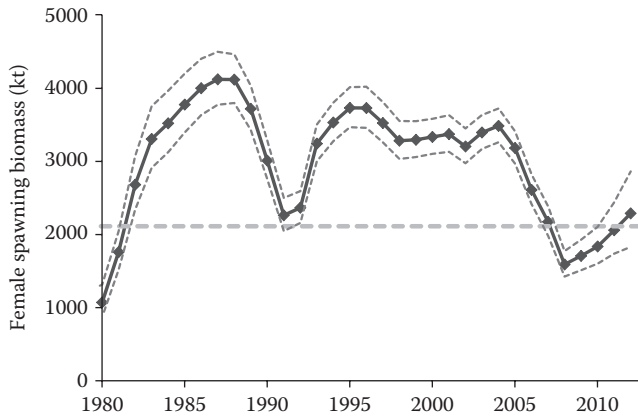


FIGURE 2.7 Estimated EBS pollock female spawning biomass and approximate 95% confidence intervals (dashed lines). Horizontal dashed line represents B_{msy} estimate.

noteworthy that in keeping with the conservation policy, catch was restricted to about 815,000 MT in 2009 and 2010 after an average catch of 1.463 million MT from 2002 to 2005. The management system responds as needed based on trends observed from resource assessment surveys and the extensive fishery observer program.

2.2.2 PACIFIC WHITING

Pacific whiting (*Merluccius productus*) catches have averaged 222,000 MT from 1966 to 2011 and landings were valued at over \$27.3 million in 2010. Catches peaked in 2005 at 363,000 MT from a low of 90,000 MT in 1980 (Figure 2.8). Utilization of Pacific whiting for surimi production showed rapid growth in the 1990s. At one time, Pacific whiting surimi represented approximately 20% of

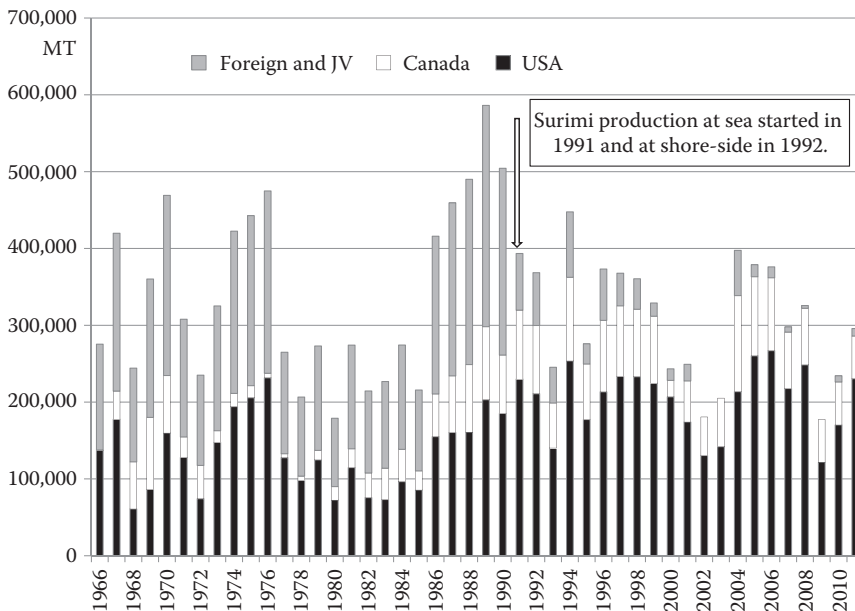


FIGURE 2.8 Pacific whiting catch by sector in 1966–2011.

surimi production in the United States, but has decreased significantly during the 2002–2003 seasons as quotas were low and prices were poor.

Pacific whiting is a type of “hake” and being a gadoid fish is related to pollock, as well as many other hake species harvested throughout the world. The majority of hake species, Argentine (*M. hubbsi*), Chilean (*M. gayi* and *M. australis*), Peruvian (*M. gayi peruanus*), South African/Namibian (*M. capensis* and *M. paradoxus*), and others, are fished primarily for products such as fillets or H&G [4]. All whiting/hakes have a white flesh and delicate taste and texture. Some are highly prized as a premier eating fish.

The whiting/hake species with the greatest combination of quality problems associated with it is Pacific whiting, harvested off the West Coast of the United States and Canada. This stock has challenging quality characteristics namely a relatively soft flesh that is often made even softer due to high levels of protease enzymes in the muscle tissue [5]. The presence of protease in whiting flesh is associated with a myxosporidean parasite that is endemic throughout the Pacific whiting stocks [6]. The parasite is microscopic and is not associated with any human health hazards. However, it appears to induce an immune response in the fish and an increased amount of lysosomal proteases called cathepsins [7,8].

During the late 1980s and early 1990s, scientists at several laboratories investigated the use of different food-grade protease inhibitors in whiting surimi production. The most active inhibitor was found to be beef plasma protein, which is commonly used at about 1% concentration [9]. By using beef plasma protein, high-quality surimi could be manufactured from either at-sea or shoreside operations. However, with the outbreak of mad cow disease, the use of beef plasma has become problematic and Pacific whiting surimi with beef plasma has been banned by most buyers or by regulations, which first occurred in Europe, then in Japan and Korea, and finally in the United States.

Several other protease inhibitors, such as egg white and whey protein, have also been identified and are used in the production of whiting surimi. Research is continuing in this area of inhibitor development from both natural sources and by using recombinant DNA. From these efforts, a soy cystatin inhibitor has shown promise for use as an enzyme inhibitor [10]. In addition, a study by Yongsawatigul and Park [11] showed that rapid heating of Pacific whiting surimi is effective for making quality surimi seafood products without the use of protease inhibitors. In spite of these efforts though, protease activity in Pacific whiting surimi continues to remain an obstacle to the marketing of this product.

Pacific whiting has been captured off the West Coast of the United States since the 1960s, primarily through foreign fisheries that could operate within 12 miles of the U.S. coastline. With the implementation of the EEZ in 1977, a combination of foreign fisheries and JV-mothership operations occurred. Because of the increasing demand for surimi worldwide, the Alaska at-sea fishing industry took an interest in utilizing whiting for surimi production.

Prior to 1990, Russia, Korea, Poland, and others either froze the majority of Pacific whiting whole or used it as an H&G product. Part of the reason for this was the presence of a muscle protease in the flesh that would rapidly break down myofibrillar proteins and prevent the formation of a surimi gel. Once this problem was solved by the use of protease inhibitors, U.S. whiting surimi production began. In 1991, 217,505 MT of Pacific whiting were harvested, mainly by at-sea operations, and the majority was made into surimi. In 1992, the first shore-based processing plants were built in Astoria and Newport, Oregon. By 1994, 250,000 MT of Pacific whiting was harvested, of which 72,000 MT landed shore-side; the majority being in Oregon where there are three surimi plants. Pacific whiting now represents over 50% of the volume of all landings in Oregon, which is a dramatic change from its traditional fisheries.

The United States has averaged 166,000 MT, or 74.7% of the average total landings over the time series, with the Canadian catch averaging 56,000 MT [12]. In the 1990s due to a disagreement between the United States and Canada, the coast-wide catches exceeded the recommended quotas. Since 2001, total catches have been below coast-wide fishery limits. The 2003 signing of an agreement on shares of hake/whiting between the two countries established the United States and Canadian shares of the coast-wide allowable biological catch (ABC) at 73.88% and 26.12%, respectively. This

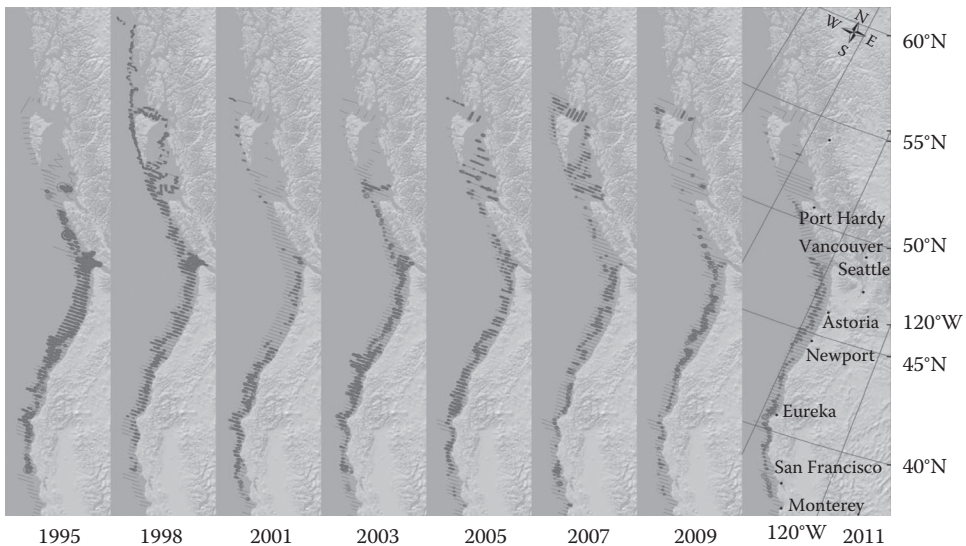


FIGURE 2.9 Pacific whiting distribution as observed during summer surveys, 1995–2011. (From I. J. Stewart et al., *Status of the Pacific Coast Groundfish Fishery through 2012, Stock Assessment and Fishery Evaluation: Stock Assessments, STAR Panel Reports, and rebuilding analyses*. Pacific Fishery Management Council, Portland, Oregon, 2012, p. 197. With permission.)

agreement was ratified as the Pacific Whiting Treaty and became effective in 2012. Management of this stock is now based on activities of four new advisory bodies. Additionally, 17.5% of the U.S. portion of the TAC is allocated to tribes (which can then transfer their allocation to other sectors).

Pacific whiting spawns in the winter off Baja California, Mexico, and then migrates northward along the West Coast of the United States during spring and summer when surveys are typically conducted (Figure 2.9). The fishery begins in May, for the at-sea fisheries, and in June, for the shore-side operations. Because of the enzymatic activity in Pacific whiting, it is critical that fish are landed and processed within 24 hour of capture. For the most part, this occurs in both the at-sea fishery and shoreside operations. Whiting boats in Oregon leave their homeports and are usually in the whiting grounds within 6–8 hours. A 2-hour tow is often successful in bringing onboard 50,000–70,000 kg of fish, which are then chilled by refrigerated seawater. Coastal boats normally off-load their catch within 12–16 hour postcapture. Longer periods cause softening and degradation of the tissue for surimi production [13].

The ex-vessel price for whiting is one of the lowest for any white-fleshed fish. Over the 1995–2003 seasons fishermen received \$US 0.025–0.05 per lb for whiting and, more recently, \$US 0.10–0.15 per lb. Fishermen are still able to make a profit at these low prices as trips can be made on a daily basis and with volumes often exceeding 120,000 lbs/trip. Pacific whiting surimi has received a lower price than pollock in the global marketplace and the majority is typically exported to Korea.

The status of the Pacific whiting stock has fluctuated in recent decades. This characteristic is largely due to a complex migratory life history and high inter-annual recruitment variability (Figure 2.10). In response, and partly due to difficulties with survey and assessment methodologies, managers have had to deal with acceptable biological catch (ABC) limits that ranged from a high in 2007 of 612,000 MT down to the 2009 recommendation of 184,000 MT. This was after a 2002 declaration that the stock was overfished and required a rebuilding plan (This was subsequently revised in 2004 when it was shown that the stocks were healthy.). An additional complication for this fishery is the constraint due to very low limits on a number of rockfish species bycatch levels.

With the establishment of the Pacific Whiting Conservation Cooperative in 1997, a rational approach to staying within such bycatch constraints was facilitated. The cooperative allocates the catch quota

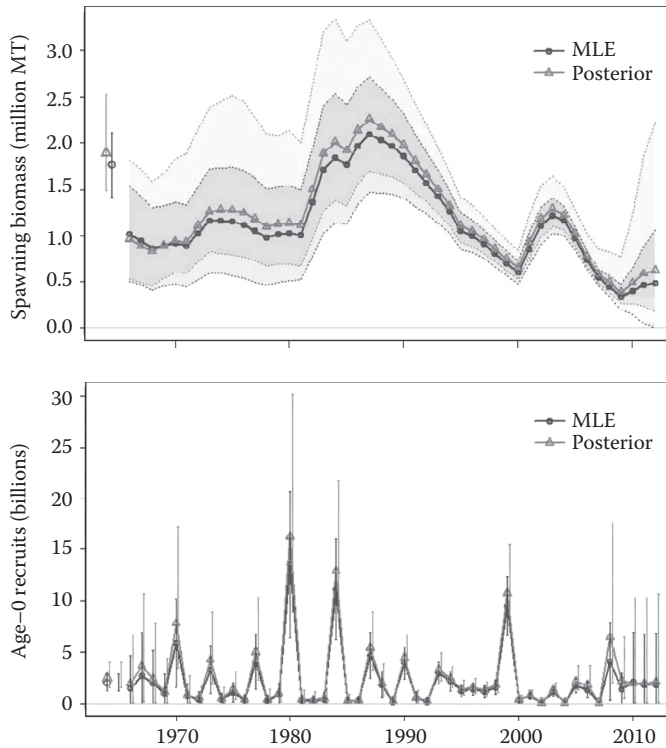


FIGURE 2.10 Pacific whiting spawning biomass (a) and recruits at age 0 (b). Estimates of uncertainty are shown as the maximum likelihood estimates (MLE) and Bayesian posterior median results. (From I. J. Stewart et al., *Status of the Pacific Coast Groundfish Fishery through 2012, Stock Assessment and Fishery Evaluation: Stock Assessments, STAR Panel Reports, and rebuilding analyses*. Pacific Fishery Management Council, Portland, Oregon, 2012, p. 197. With permission.)

among members, thereby ending the “race for fish” and allowing them to use the quota more efficiently. In addition to managing bycatch limits (through the use of sharing bycatch hotspot information), the fishery has become less wasteful and produces a higher quality product [14]. Additional catch-share measures extended to the shore-based trawl fishery also include full catch accounting, with 100% observer coverage, which leads to reduced bycatch and better data for stock assessments.

2.2.3 OTHER FISHERY RESOURCES IN NORTH PACIFIC

A number of other North Pacific species have been used to produce surimi, including Pacific cod, salmon, Pacific herring, Atka mackerel (discussed under the pelagic species section), and arrowtooth flounder.

Pacific cod (*Gadus macrocephalus*) is one of the most sought after groundfish species in the North Pacific and is sold in a wide variety of markets and product forms. Whereas small amounts have been used for surimi production, the primary fleet that holds the quota has limited access to processing facilities (for the at-sea component) and the other product forms provide better prices to the fishermen. Salmon species and herring are also suitable for making surimi but similar to Pacific cod, and the alternative markets are seen as prohibitive toward developing anything but some very small niche markets.

Arrowtooth flounder (*Atheresthes stomias*) is a relatively large flounder found off the West Coast of the United States northward to the Bering Sea. The ABC is estimated to be over 152,000 MT for 2013

in the Eastern Bering Sea and 210,000 MT in the Gulf of Alaska [15]. There were minimal harvests of arrowtooth flounder from these regions for several reasons. Arrowtooth flounder suffers from the same quality problems as Pacific whiting, that is, a heat-stable protease enzyme in the muscle tissue [16]. This gel softening can be overcome by food-grade protease inhibitors, such as beef plasma protein, and early commercial runs of arrowtooth surimi have proven successful with these inhibitors. Babbitt et al. [17] have also developed a new surimi processing technique using a decanter in place of washing operations. This has worked well with arrowtooth, and preliminary trials have been successful.

Another major concern for arrowtooth utilization in the high volume surimi industry is the lack of automated machinery for cutting the flesh (J.K. Babbitt, personal communication, 1998). Most filleting operations or mincers used in the surimi industry are designed for round fish, such as pollock and whiting. Most flatfish filleting machines are geared for fish fewer than 20 inches, although they could be reconfigured for larger fish if the demand was sufficient. In addition, there are concerns about size uniformity in arrowtooth. Sizes ranging from 500 to 5000 g are common; therefore, it is usually more economical to hand fillet the fish.

Whereas the arrowtooth flounder resources are minimally exploited in Alaskan waters, the potential to increase catches is impeded by the fact that Pacific halibut is commonly taken as bycatch. Pacific halibut is highly valued and for most vessels (except those with dedicated halibut quota) they are categorized as having “Prohibited Species Catch” limits. These limits pose challenges to various fishing fleets already constrained by hard limits set on other more valued species. Hence, the value of catching arrowtooth flounder (and reaching a halibut cap sooner) must be weighed against catching other species such as Pacific cod or rockfish. Until the fishing technology/management issue is resolved, the use of arrowtooth for surimi production will be on a limited basis.

2.2.4 SOUTHERN BLUE WHITING AND HOKI

Southern blue whiting (SBW) (*M. australis*) and hoki (*M. novaezelandiae* and *M. magellanicus*) are restricted in distribution to the sub-Antarctic waters [18]. Hoki is a major fishery in New Zealand, Argentina, and Chile. Several research groups have investigated hoki as a surimi source and have found hoki and SBW surimi to be of excellent quality [19–22] that is similar to pollock surimi. Hoki surimi proved to be of excellent quality and high gel strength. Most of the supply is utilized by Japan and Korea. SBW is considered as the surimi with the highest functionality in the market due to its high elasticity and setting ability.

During the second half of the 1980s, hoki surimi potential reached its peak and in 1988 approximately 23,000 MT of surimi was produced, representing 3% of the world’s surimi supply. During the 1990s there was a shift away from surimi production and the majority of the hoki harvested is now used for fillets and frozen blocks. Despite a large quota (250,000 MT), Japanese vessels process only a small volume of hoki surimi in New Zealand and the volume processed in Chile and Argentina on factory trawlers has also declined. By 2012, only three factory trawlers remained (one in Chile, two in Argentina) to process hoki and SBW surimi.

The quotas for hoki in Chile and Argentina are managed under a system of Total Allowable Catch and Individual Quotas allocated per company. The Chilean quota for 2011 was 123,000 MT and decreased to 98,000 MT in 2012. Hoki surimi production in Chile has varied from 1300 to 1900 MT in the years 2005–2011. The Argentina quota for 2011 was 150,000 MT, but the catch was only 70,000 MT as few vessels have the ability to catch this fish. The quota for 2012 was reduced to 140,000 MT, but the catch is expected to increase due to stronger fishing effort. The hoki fishery in Argentina was certified as sustainable by MSC in 2012. The two factory trawlers still operating in 2011–2012 represent 25% of the catch and process 3000–4000 MT of hoki surimi per year, while the remaining volume of the catch is processed into fillets or H&G.

There are two distinct populations of SBW that are actively fished, one of which, *M. australis australis*, is found around the Falkland Islands and Argentine Patagonia in the western South Atlantic and also off South Georgia, South Shetland, and South Orkney Islands, and in the southeastern

Pacific, off Chile. The other population (*M. australis pallidus*) lives on the various banks and rises around the South Island of New Zealand.

SBW surimi is produced in Argentina and Chile. After peaking in 1998, production decreased by the late 2000s down to 3500 MT in Chile and 1000 MT in Argentina. Nevertheless, with vessel improvements, Argentina production was expected to reach 3000 MT in 2012. SBW is often contaminated with parasites that make this fish unsuitable for fillet production and, therefore, most of the catch is directed toward surimi production. The surimi is of very high gel strength and high deformation, in competition with high-grade Alaskan pollock. This surimi is of premium quality and is used for high-end products in Japan. The total production of SBW and Hoki surimi in South America is expected to reach 11,000–12,000 MT in 2012.

2.2.5 NORTHERN BLUE WHITING

The Northern blue whiting fishery has traditionally been oriented to fish meal production. However, there was a small volume of H&G fish used for human consumption. After years of overfishing, with a total catch of more than 2 million MT, the resource was becoming depleted. The countries involved in the North Atlantic fishery (Norway, Russia, EU, Iceland, and Faroe Islands) finally reached an agreement over quota distribution by the mid-2000s and agreed to reduce the fishing pressure in order to stabilize and rebuild the resource. The quota for Northern blue whiting was gradually reduced to about 500,000 MT by 2010 and cut to 40,000 MT in 2011. The fishery scientists later agreed this cut was too extreme and unjustified. The quota was then reestablished to 390,000 MT in 2012 and is expected to slowly increase in the coming years. With a stabilized quota, Northern blue whiting has the potential for further growth both for factory trawler and shore-plant production. However, the increasing demand and high prices for frozen fish, particularly in West Africa, are putting pressure on the economic viability of surimi processing from this species.

Since the early 1990s, a French factory trawler has produced Northern blue whiting (*M. poutassou*) surimi. Production volume increased and reached over 10,000 MT when a second vessel started operation in the Faroe Islands in 2005–2007. The Faroe's vessel was removed from the fishery in 2008 and only the French vessel remained in operation with a production of around 3000–4000 MT per year.

Northern blue whiting gives a high-quality surimi similar to SBW. This surimi has the advantage of high elasticity (high deformation value) as long as the fish is processed fresh. The fish quality decreases rapidly after harvest. In 2003, shore-based plants were also built to process surimi from frozen fish in Russia and from fresh fish in the Faroe Islands but insufficient and irregular supply of raw material to the factories, low market price of surimi, and higher value of fish meal stalled these operations. Surimi produced from frozen fish showed extremely low quality simply due to the nature of low thermal stability of this cold water species (see Chapter 3). Northern blue whiting surimi is also reported to set very quickly and is sensitive to temperature abuse.

2.2.6 OTHER WHITE FISH RESOURCES FROM SOUTH AMERICA

Chilean whiting (*M. gayii*) also called “hake” has been used in limited quantities by surimi shore plants in Chile from 1994 to 2001, yielding about 1000 MT/year. During this time period, the “Olympic” fishing quota for hake was incentive for the fishing companies to maximize the catch as soon as the season opened. In 2001, Chile adopted the individual transferable quota (ITQ) management system, which allocated individual quotas to the fishing companies involved in the fishery. Since then, hake surimi production stopped as fillets and H&G fish have brought higher economic returns than surimi.

2.3 TROPICAL FISH

The main fish species used in Southeast Asia for production of surimi are threadfin bream (*Nemipterus* spp), big eye snapper (*Priacanthus* spp), croaker (*Pennahia* and *Johnius* spp), lizardfish

(*Saurida* spp), goat fish/red mullet (*Upeneus* spp and *Parupeneus* spp), sea bream (*Evynnis* spp), and hairtail, also called ribbon fish (*Trichiurus* spp). These species are also commonly used in southern sub-tropical Japan and are known as itoyori, kintokidai, guchi, eso, himeji, renkodai, and tachuo, respectively [23]. Other species are also used, depending on availability (seasonality) and price. These include conger eel (*Congresoxs* spp), barracuda (*Sphyræna* spp), leather jacket (*S. cirrhifer*, *N. modestus*), various types of mackerel and sardines, and practically all bycatch that is of too small size or not suitable for commercial sale (further processed fish but surimi).

Fishing in Southeast Asia is mostly artisanal and is not integrated with fish processing. Along with surimi fish, fishing vessels target other species such as shrimp or squid. Surimi fish are a low value product of the fishery. However, these fish represent a volume of around 70% of the total trawler catch and is essential to the economic viability of vessels. The fish are auctioned at ports and surimi factories compete with the fresh fish market, fresh fish mince processors (unwashed fish mince is often used for fish ball), and dried fish producers (large volumes of fish also go to fish meal). In recent years, the strong demand for frozen fish by China has put additional pressure on supply and prices of fish for surimi plants in neighboring countries, like Vietnam and India.

There have been continuing questions regarding fishery management and sustainability of resources in Southeast Asia. Many fishing grounds, especially those located close to the shores of the processing countries, are claimed to be overfished. Some of the main fishing and processing countries like Thailand, India, and China manage their resource through fishing ban periods of about 2 months during the spawning season (June–July) to let the resource reproduce. In Vietnam, fishing stops for 1 month during the Lunar New Year festival.

Surimi production from tropical fish continues to grow and tropical fish surimi has become a major player in the market place in competition with and as a complement to Alaskan pollock and other cold water species.

2.3.1 THREADFIN BREAM (ITOYORI)

The use of threadfin bream for surimi production has increased over the past decade and will continue to play a major role in surimi markets, especially in Southeast Asia where this species is preferred to Alaskan pollock for its resistance to temperature abuse (easy to process). Threadfin bream gives high-quality surimi with strong gel strength [24]. Threadfin bream belong to the family *Nemipteridae* and more than 10 species are commonly found in the Indo-West Pacific region in tropical and sub-tropical waters. Threadfin bream forms an important part of the trawl catch with the greater catches being landed in Thailand, India, Vietnam, Indonesia, The Philippines, and Malaysia.

These fish are benthic, inhabiting marine waters on sandy or muddy bottoms usually in depths of 20–50 m, and feed on small benthic invertebrates and small fishes. Males are usually larger and some species may be protogynous hermaphrodites. Two prolonged spawning seasons occur from November to February and another from May to June. Catches of threadfin bream are usually not identified by species, but in Southeast Asian the main species caught include: *N. peronii*, *N. marginatus*, *N. mesoprion*, *N. nematophorus*, and *N. japonicus* [25]. Most of these species are 10–15 cm in length. The larger-sized individuals are usually sorted out for direct consumption sale. The size of fish typically used for surimi processing is less than 30 g/fish. Fish are manually headed and gutted before subjecting to deboning and the surimi factories employ a large number of people for fish cutting. Fish cutting is difficult to mechanize because of the large size variation of the fish and the necessity to process many different species.

The supply of “fresh-chilled” threadfin bream to the surimi factories in Thailand now comes from Southern Thailand with significant landings from the Andaman Sea area. A large volume is also obtained from Myanmar waters. Since Indonesia discontinued fishing licenses to Thai fishing vessels, most factories that were using “frozen on board” threadfin bream caught in the Indonesian waters have stopped this processing and only fresh fish is now processed in Thailand.

India, Vietnam, and China increased production considerably during the 2000s and surpassed Thai production of threadfin bream surimi. Malaysia, Indonesia, Myanmar, and Pakistan also process itoyori surimi.

Itoyori surimi is well accepted in Japan, particularly in the southern part, and is the raw material of preference in Southeast Asia because of its white color, smooth texture, strong gel-forming ability, and easy processing. This has resulted in increased production of surimi from threadfin bream in all countries where itoyori are available.

2.3.2 LIZARDFISH (ESO)

In Southern Japan, lizardfish (*Synodontidae*), which is *eso* in Japanese, has long been considered a high-grade raw material for surimi with high meat yield, white color, unique flavor, and firm gel-forming ability [26]. However, the freshness and gel-forming ability decreases quickly over time, even in ice, therefore only fresh raw material is used in Japan.

In the Association of Southeast Asian Nations (ASEAN) region, lizardfish is considered a low-value fish. It gives a white surimi with low gel. Lizardfish (*Saurida waniese*) is commonly used in Thailand for dried fish snacks and is used in combination with itoyori for the production of crabsticks, fish balls, and other surimi products. Lizardfish surimi also became an alternative to jack mackerel surimi in Europe to mix with Alaskan pollock for crabstick production and is used for fish cakes in Japan and Korea. The main species of lizardfish in these countries are *S. tumbil* and *S. undosquamis* (the usual size is 10–20 cm).

Studies by Nozaki et al. [27] and Yasui et al. [28] indicate that the gel-forming ability of lizardfish falls rapidly during ice storage, due to the formation of formaldehyde and dimethylamine. The improvement of the gel-forming ability of lizardfish by washing the minced meat with sodium pyrophosphate solution has been reported. Ng et al. [29] showed that sodium pyrophosphate leaching of lizardfish (*S. tumbil*) was effective when formaldehyde levels did not exceed 50 ppm.

2.3.3 BIG EYE SNAPPER (KINTOKIDAI)

Big eye snapper (kintokidai in Japanese) belong to the family *Priacanthidae*. Two species are represented in the South China Sea area: *Priacanthus tayenus*, which is more abundant, and *P. maracanthus*. Both species have a bright crimson color with a thick, tough skin. Unlike threadfin bream, which often have burst-belly when kept in ice for too long, bigeye snapper has a longer shelf-life in ice.

Two different types of kintokidai are found in Southeast Asia: The first one of large size and red color (100–200 g) gives white meat with high gel while the second one of small size (30–70 g) and usually grayish color gives darker meat with low gel. Big eye snapper is abundant in trawl catch and often landed in substantial quantities. Owing to its appearance and thick skin, it is not consumed directly and is therefore a suitable raw material for surimi manufacture. It can reach a size of 30 cm; however, the average commercial harvest for surimi is 10–15 cm.

Big eye snapper of large size is often combined with threadfin bream in Vietnam to improve gel strength while the smaller size is used in mixed fish, low-grade surimi, which has a dark color and low gel strength.

2.3.4 CROAKER (GUCHI)

Croaker (*Sciaenidae*) includes two main species, each having different characteristics:

- Jew fish (kiguchi in Japanese) gives a white high gel surimi that has long been a preferred species for the traditional kamaboko industry in Japan, especially in the Odawara area and Southern Japan. Kamaboko made from croaker or “kiguchi” surimi has a distinctive taste

and texture, distinguishing it from the relatively blander taste of kamaboko made from Alaska pollock. Surimi production from kiguchi in India has been limited in recent years due to the high price of raw fish material.

- Croaker (shiroguchi in Japanese) gives a low-grade surimi (low gel, darker color). It is processed as a single species in India and is used in mixed fish surimi in Vietnam and China.

In the sub-tropical areas of Japan, China, and Taiwan the species of croaker commonly used are the blackmouth croaker (*Atrobucca nibe*), white croaker (*A. argenteus*), and yellow croaker (*P. polytis*). Surimi production from these species is limited to smaller sized fish that are caught since this species is sold at a high value in the fish market.

In the ASEAN region, the croaker species used for surimi are comprised mainly of *Pennahia* and *Johnius* spp. These species are abundant in the trawl fishery, especially from the coastal, muddy waters off Sarawak in the South China Sea and off Myanmar in the North Andaman Sea, near large river mouths. The usual size of croaker ranges between 5 and 10 cm and is usually sorted according to size rather than species. Croaker surimi from these species is generally darker in color.

2.3.5 OTHER SPECIES

Goatfish (*Upeneus* spp) and red mullet (*Parupeneus* spp) are landed in Thailand, India, Vietnam, and Indonesia. The bigger sized fish (100–200 g) are sold whole round or processed into skin-on fillets for Europe and other markets. The smaller sized fish are processed into surimi called himeji in Japanese. It is slightly pinkish in color due to its skin color and usually has low gel strength.

Hairtail or ribbon fish (*Trichiurus lepturus*) has an elongated and compressed body, is steel-blue in color with a metallic sheen, and is silvery-gray when dead. It is common in the Indo-Pacific region, up to Japan in the north and southward to Queensland, Australia. It is commonly caught in coastal waters and trawling grounds, feeds on crustaceans and fish, and has a typical size of 70–90 cm, with a maximum of 110 cm. Ribbon Fish surimi composed a large portion of the Chinese surimi production, but this production has declined since 2010 due to the reduction of fish landings and high demand for the table fish market in China. Large-sized fish caught all over Southeast Asia are exported to China while smaller sizes go to surimi production. Although it has a low gel-forming ability and the surimi is generally dark in color, it is used popularly in Korea and Japan for fried surimi seafood because of its *good* flavor and cheaper price.

Sea bream is another species that has been caught in large volumes in the South China Sea and landed both in the northern part of Vietnam and southern part of China. The two main species are Yellowback seabream (*Evygnnis tumifrons*) (renkodai in Japanese), mostly caught in China, and threadfin porgy or cardinal porgy (*E. cardinalis*) (hirekodai in Japanese), landed in both Vietnam and China. Seabream gives high quality surimi with high gel and white color, similar to threadfin bream surimi. One problem reported in both Vietnam and China with this species is a chemical (chlorine-like) smell that sometimes develops in the fish meat due to the fish feeding on seaweed that develops a strong smell at certain times of the year in some fishing grounds.

During the fishing season in Vietnam, another fish processed into surimi is flying fish (*Cypselurus* spp) (tobiuo in Japanese), which produces surimi with acceptable gel forming ability, but dark color. This surimi has been used in Japan and Europe as a substitute for jack mackerel since the mid-2000s. In addition, several other fish species are used for surimi manufacture although they are not as abundant as the above species. These include the pike-conger eel (*hamo*), barracuda (*kamasu*), leather jacket (*klathi*), reef cod (*hata*), and others.

Pike-conger eel (*Muraenesocidae*) has a cylindrical, eel-shaped body without scales, with three main species caught in the Southeast Asian region: *Congresox talabonoides*, *C. talabon*, and *Muraenosox cinereus*. The first two species are generally larger (usually about 150–200 cm in total length) and used to be the preferred species for fish balls and fish cakes. The meat is extremely white and has a high meat yield of about 68%. Pike-conger eels are found from the coast of India eastward

to Celebes, the Philippines, and the South China Sea. The fish live over soft bottom down to 100 m, feeding mainly on bottom-living fishes, and are caught mainly by hand-lines and trawl. Production of surimi from conger eel is extremely limited due to the high price and low availability of raw material.

Barracuda (*Sphyraenidae*) is sometimes used as raw material for surimi when in season, although the gel-forming ability is generally low. The main species used include the smaller species *Sphyraena langsar* and *S. obtusata*. The larger species *S. jello* is usually used as salted-dried fish.

Leather jacket (*Stephanolepis cirrhifer*, *Navodon modestus*) has a hard, thick skin and an abundance of bones. It is occasionally processed into surimi in the southern region of India and gives a low-quality grayish surimi.

The Chinese communities in Southeast Asia consider fish balls as a premium fish jelly product and have, in the past, used selected species based on their strong gel-forming ability and protein stability to the relatively high temperatures in the region. The two fish species initially used for making premium quality fish balls include coral fish (*C. erythrogaster*) and wolf herring (*C. dorab*). These two species form stable gels that are “slow setting” and “fresh” fish balls are often formed manually in the markets as made to order products. In Singapore, there are also specialty fish ball-noodle stalls well known for their “coral fish” fish balls. Nowadays mostly itoyori, imported from Thailand, Vietnam, India, and Indonesia, is used for this purpose.

Bereche (*L. pacificus*), lumptail sea robin (*P. stephanophrys*), and other species have also been used in Peru to produce surimi.

2.3.6 TROPICAL SURIMI PRODUCTION TREND BY COUNTRY

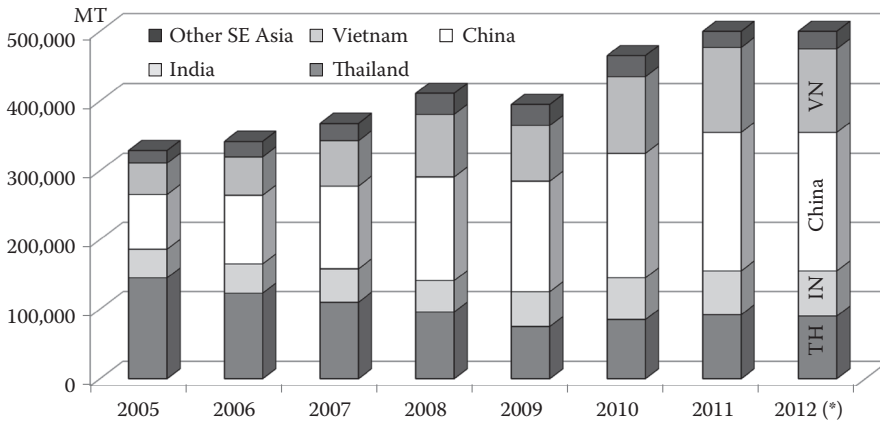
In the early 2000s, it was estimated that about 200,000 MT of surimi was made from tropical fish. The largest surimi producing country was Thailand at 140,000 MT (50% itoyori, 15% kinmedai, 15% eso, and 10% himeji), while India produced 40,000 MT (70% itoyori), Vietnam 20,000 MT, and China around 10,000 MT. Malaysia, Indonesia, Myanmar, Pakistan, and the Philippines also developed their surimi industry using tropical species. By 2011–2012, the production volume of surimi in Southeast Asia was estimated at around 500,000 MT. The main processing countries include China (200,000 MT) and Vietnam (140,000 MT) while production decreased in Thailand (90,000 MT) due to restrictions of fishing, reduced fish supply from Indonesia, and stabilized India (60,000 MT) (Figure 2.11). The surimi industry in these countries has large processing over-capacities and the production volume depends mostly on fish landings and market conditions. Other surimi producing countries include Malaysia (15,000 MT), Indonesia (12,000 MT), Myanmar (200 MT), Pakistan (2000 MT), and the Philippines (1000 MT), which also have large fish resources and a potential for further growth.

2.3.6.1 Thailand

Surimi production started in Thailand in the late 1970s with the support of Japanese importers. In the late 1970s, the fish species used as raw materials for surimi, especially Threadfin bream and Big eye, were abundantly found in Thai waters, primarily in the Gulf of Thailand and Andaman Sea. According to the Thai Government, in 1963 fishing efforts for Threadfin bream yielded 276 kg/hour. In 1988, only 80 kg/hour and only 20 kg/hour were caught in 2000. However, Thailand continued to expand surimi production by fishing in neighboring countries, such as Indonesia and Myanmar.

Indonesia represented up to one third of the fish brought to Thailand for surimi production. Most of this fish was caught by large freezer vessels operating in the eastern sea of Indonesia, frozen on-board, and transferred to Thailand for processing by carrier vessels. This frozen fish represented over 30% of the fish processed in Thailand and was usually mixed with fresh fish to obtain acceptable characteristics. This is probably the only experience of successful surimi processing from frozen fish and was possible because of the better resistance of protein from tropical fish to denaturation.

Owing to the fish harvested from Indonesia and Myanmar, Thai surimi production increased to over 150,000 MT by the year 2005 despite reduced fishing in Thai waters. However, by 2006–2007,



	2005	2006	2007	2008	2009	2010	2011	2012 (*)
Thailand	145,000	123,000	110,000	96,000	75,000	85,000	92,000	90,000
India	41,000	42,000	48,000	45,000	50,000	60,000	63,000	60,000
China	80,000	100,000	120,000	150,000	160,000	180,000	200,000	200,000
Vietnam	45,000	55,000	65,000	90,000	80,000	110,000	122,000	140,000
Other SE Asia	18,000	22,000	25,000	30,000	30,000	30,000	30,000	35,000
Total	329,000	342,000	368,000	411,000	395,000	465,000	507,000	525,000

FIGURE 2.11 Surimi production from tropical species by country, 2005–2012. * Indicates estimated number.

the Indonesian Government did not renew the fishing licenses for Thai vessels and changed regulations that prohibited most of the Thai fishing vessels from entering Indonesian waters. As a result, surimi production dropped and recently stabilized at around 90,000 MT.

Thai surimi has the reputation of high quality. Around half of the production is used in Thailand while the remaining half is primarily exported to Japan where Thai surimi is considered to have the best quality in Southeast Asia.

2.3.6.2 India

The Indian surimi industry developed in the 1990s on the west coast of India under the influence and support of Japanese importers as well as with Korean and Thai assistance. Production rapidly grew to reach around 20,000 MT by the year 2000, 40,000 MT by 2005, and 65,000 MT by 2010. Nevertheless, production seems to have reached a maximum of fish availability. The main production is on the west coast, with areas including a large shallow shelf: in the northwest (Gujarat), center west (Maharashtra), and southwest (Goa, Karnakata). Fishing is regulated and the measures to maintain the resource include a fishing ban of about 2 months during the monsoon season (main spawning season in May–July), ban on destructive fishing gear and methods, minimum mesh size for the fishing nets, and some protected areas. Over the past years the industry has consolidated as some factories closed down mostly due to issues with wastewater disposal. However, new factories keep developing, which results in a strong competition for raw material.

Threadfin bream is the main species (70%) used for surimi production and various other species include lizard fish, croaker, big eye snapper, goat fish, ribbon fish, and sardine. The average fish size is bigger than in Thailand and the freshness of fish is usually good since the fishing fleet is constituted of small vessels (10–12 m) operating on short trips of 3–5 days.

Indian surimi production is mostly exported to Japan where it competes with Thai surimi and to East Europe. India utilizes a small portion of its production to process crabsticks for export to Europe and the United States (around 10,000 MT in 2010).

2.3.6.3 Vietnam

Vietnam has traditionally been an active fishing nation with over 130,000 fishing vessels, mostly artisanal. In 2010, over 1 million fishermen were employed, which generated work for several million workers in the fish processing and fishing-related industries. Vietnam has five main fishing ports located in the south (Vung Tau, Rach Gia, Ca Mau), central (Da Nang), and north (Than Hoa). The main fish landings and surimi production occur in the southern part of Vietnam. Since the Vietnam fishery is not managed by regulations, coastal fishing grounds have been over-exploited in recent years, causing Vietnamese vessels to fish near the borders of Malaysia, Thailand, Indonesia, and China.

Surimi production started in the 1990s, mostly supported by Korean importers. Production grew in the 2000s supported by exports to Japan, Europe, Russia, and Southeast Asia and was projected to reach over 100,000 MT by 2010. During these years, many small factories (over 50) were established, creating tough competition for raw material. As its surimi production was initially directed mostly to Korean processors of fried fish cakes, the main product was low-grade surimi with mixed species; approximately half of Vietnam surimi production is currently exported to Korea. In the mid-2000s, some companies developed better quality product from threadfin bream, lizard fish, and flying fish and successfully entered Japanese and European markets. Later, they expanded into Southeast Asia (Thailand, Singapore) and China, after their demand surpassed local supply capabilities.

The absence of fishing regulations and resource management are concerns for the future of the Vietnam surimi industry. However, in spite of reported overfishing, erratic and somehow unpredictable fish landings, and poor quality for most of the production, Vietnam surimi production continued to grow and reached 140,000 MT in 2012 as high surimi prices could support higher fishing costs (Figure 2.11).

2.3.6.4 China

China has a large coastline and long fishing history. Its large fishing fleet operates in Chinese domestic waters, overseas in international waters, and through fishing licenses. Surimi production in China started in the 1990s with support of Japanese, Korean, and Thai partners. Then rapidly grew in the 2000s with the construction of many shore-based surimi factories from 2000 to 2010 and increased fishing efforts in the South China Sea. As a result, China obtained a leading position in surimi production by the end of the 2000s.

No precise statistics are available regarding surimi production in China. Since the domestic market absorbs the largest portion of the surimi production, estimates can be calculated based on data collected from producers. Industry players estimated the Chinese domestic surimi production at around 200,000 MT in 2010. The production volume is reported to have stabilized and even decreased in 2012 due to insufficient fish supply.

As the potential for increasing production from sea fish is limited, Chinese producers have been developing production of surimi from fresh water fish, particularly carp. This production is estimated at around 30,000 MT in 2011–2012 and is growing to respond to the domestic demand for more surimi raw materials. In addition, freshwater fish surimi has become increasingly popular, particularly in central regions where marine fish surimi is not readily available.

China has been a large surimi exporter and exported 70,000 MT, mostly ribbon fish and low-grade surimi, to Japan and Korea in the period of 2008–2010. Since 2011, the export volume decreased as prices increased and local demand absorbed most of production. China also has a strong domestic market for surimi. Crabstick production both for domestic and export to the United States and Europe is estimated at around 30,000–40,000 MT (50:50 for export and domestic market). Fish ball production for the domestic market has also developed rapidly since 2000 from the southern regions to all coastal areas up to northern China. The Chinese domestic market for fish ball is estimated today at over one million MT. Fish and meat are often mixed together in fish-meat balls

and the proportions may vary depending on the products and the price of raw materials. Dim sum or fish cakes made using surimi as an ingredient also contributes to a growing market. The statistics of the Fishery Bureau from Ministry of Agriculture reported 960,000 MT for total production of surimi seafood in China in 2010. This market keeps growing at double digit rates and demands more surimi supply.

2.3.6.5 Malaysia

On the basis of market information and discussions with local surimi producers, the surimi production in Malaysia is estimated to be approximately 15,000 MT (or 20,000 MT if unwashed fish mince or fresh fish meat is used domestically for fish ball and fish cake production). The main fish species used for surimi production in Malaysia are the same as other Southeast Asia countries: Mostly threadfin bream, big eye, lizard fish, and croaker while barracuda was reported as a significant supply in the mid-2000s. Surimi is used locally (as well as fish mince) for production of fish ball and fish cakes for the domestic market, for crabstick production (for domestic and export markets), and for export to Japan and Singapore. The production is reported to have declined in recent years due to insufficient fish supply and the leading processor (QL Food) relocating a part of its operation to Indonesia.

2.3.6.6 Indonesia

Indonesia is the largest country, has the longest coastline, and the largest shelf area in Southeast Asia. Consequently, Indonesia probably has the largest fish resource in Southeast Asia for surimi production. Thai fishing vessels used to harvest over 300,000 MT of fish from Indonesian waters for Thai surimi factories in the early 2000s until the Indonesian Government restricted access of their domestic waters to foreign fleets. One limitation to the development of the surimi industry is that large fishing grounds are located in the east of the country around unpopulated islands with no infrastructure, no water, no electricity, and no logistics, while the fishing grounds around the populated and industrialized areas in the west have already been largely depleted. Consequently, surimi production has been limited to a few factories located mostly in Java, which processes 10,000–12,000 MT of surimi, most of which is exported to Korea, Japan, Singapore, and Taiwan. Nevertheless, new projects of surimi factories fueled by foreign investments, particularly from Korea, Malaysia, and Japan, continue to develop. It can be expected that Indonesia will become a more significant player in surimi production in Southeast Asia in the coming years.

2.3.6.7 Myanmar

Myanmar has an adequate fish resource with a long coastline along the Andaman Sea. Surimi production started in Yangon in the mid-1990s, and several plants were established in the early 2000s supported by foreign investment from Japan, Malaysia, and Thailand. Production nevertheless did not increase significantly and has been limited to a couple thousand MT partly due to the political uncertainty of the country, lack of guarantee for foreign investment, and problems with corruption. Therefore, most of the fish caught in the country are sold to Thailand where it represents a significant source of supply for surimi factories.

2.4 PELAGIC FISH USED FOR SURIMI

Pelagic fish have traditionally been used in Japan for surimi production, particularly Atka mackerel (*Pleurogrammus monopterygius*). This species is technically unrelated to other mackerels (its in the “greenling” family) but nonetheless results in surimi that has a dark color, a relatively low gel strength, and a strong “fishy” taste. It is used for traditional, low-priced surimi products in Japan (primarily fried fish cakes). There has been an active research program in Japan using similar “blue fish” species to show the potential use of these species for surimi products.

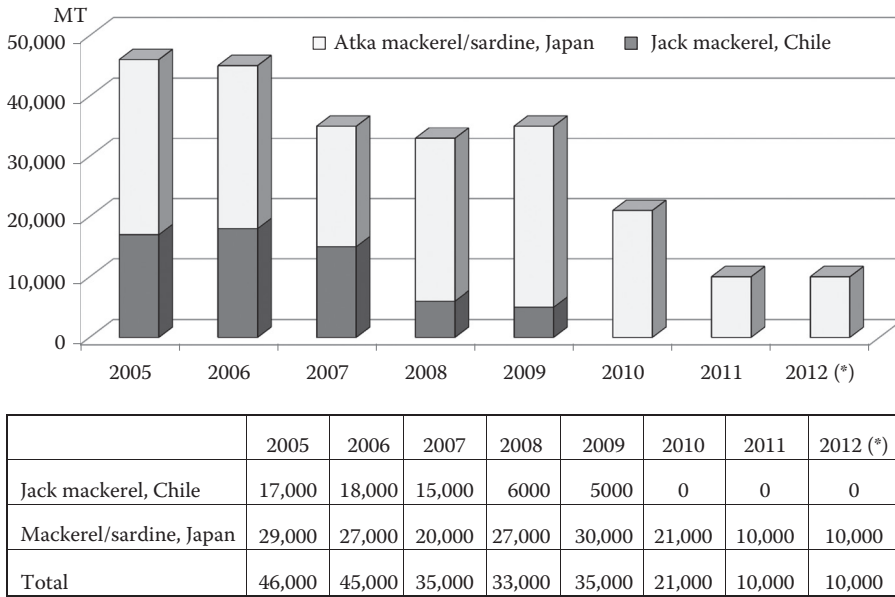


FIGURE 2.12 Surimi production from mackerel and sardine, 2005–2012. * Indicates estimated number.

The production of Atka mackerel surimi in Japan was complemented in the early 1990s by production of jack mackerel surimi (*Trachurus murphyi*) from Chile where three factories operated. This was stimulated by strong demand from Japan for this type of surimi. However, the Japanese market subsequently decreased for these surimi products, which prompted a drop in Atka mackerel surimi prices. This then led to a decrease in the production of this type of surimi from 60,000 MT down to 40,000 MT by the end of the 1990s (Figure 2.12).

Production of jack mackerel in Chile also collapsed by the end of the 1990s due to the absence of demand from Japan. Most factories in Chile stopped production except for the main producer that was able to adapt by supplying Europe. The innovation to use Chilean jack mackerel for crabstick production was due to a change in processing technique. The new technology switched from using a screw-press to decanters. This resulted in jack mackerel surimi that had a low fat content (resulting in a less “fishy” taste). Also, the use of titanium dioxide or vegetable oil whitened the final product and allowed European processors to substitute one third of Alaskan pollock with cheaper jack mackerel surimi for processing crabsticks. Jack mackerel surimi exports to Europe reached close to 20,000 MT by 2005–2006.

Unfortunately, the large harvests of Chilean jack mackerel (peak catches averaged over 4 million MT/year from 1994–1996) resulted in severe depletion and in 2010–2012 catches averaged only 583,000 MT (whereas the mean catches from 1990–2012 were approximately 2.3 million MT). This decline might partly be due to poor recruitment conditions but more likely were due to overfishing by Chilean and other international fishing fleets operating offshore Chilean waters. In 2010, the Chilean jack mackerel surimi production ceased partly due to the low level of catch, but also due to a competitive west-African market for frozen jack mackerel from at-sea processors (mainly EU vessels).

Atka mackerel production into Japan also dropped from around 30,000 MT in the 2000s down to about 10,000 MT since 2010 (Figure 2.12). These poorer fishing conditions led to a shortage of supply, which resulted in a price increase for this kind of surimi.

Some efforts have also been undertaken to make surimi from anchovies (*E. ringens*) in Peru. The factory is located in the north of Peru (Paita), where production has been limited due to unstable landings in this location. Production was estimated to be less than 1000 MT in 2012.

Sardine has also been used as a resource to process surimi. Besides Japan and India, which process small quantities of sardine surimi when the landings are abundant, tentative plans have also been made to process sardines in Morocco. The first factory was established in the 1990s by a French company that used this surimi in combination with Alaskan pollock for processing crabsticks. However, production stopped after a few years of operation because of a lack of competitiveness of this raw material compared to other sources due to an unstable supply of raw material as well as other factors. A new factory was recently built in Dakhla in the south of Morocco by the company Maroc.

2.5 GIANT SQUID SURIMI

The resource of giant squid (*Dosidicus gigas*), called “pota” in South America is abundant; the biomass in Peru alone is estimated at over 1 million MT with an annual catch of 400,000 MT. As a result of the large variations in water temperature resulting from “El Nino” and “La Nina” in the Pacific Ocean, giant squid migrate from the middle part of Chile to Mexico and even California. The resource is usually found abundant in Peru where it can be caught close to the coast by a fleet of artisanal vessels.

The processing of surimi from giant squid was developed in the mid-2000s in Peru and Mexico. Giant squid meat has the particularity to develop off smell and off taste due to the production of urea and ammonia components in its muscle, which need to be washed out by soaking the fillets in buffer solutions prior to processing. Other issue for surimi production is that the minced meat gives meat particles of very small size, while a large portion of the proteins solubilize when the fillet is minced. This makes protein recovery practically impossible with traditional surimi technology. For these reasons, production has been mostly in the form of mince produced from treated squid fillets, which is then stabilized by cryoprotectants. This surimi has a very white color, but gives a low gel similar to egg white.

Recently, new processing technologies have been developed to solubilize refloculate and separate the protein using pH shift and/or salt addition. The surimi obtained by this process is very white and exhibits improved gelling ability. These processes are still in the industrialization stages and volumes produced are limited. However, this development seems to be promising for the future commercialization of squid surimi with these techniques.

Production of squid surimi reached 5000–6000 MT in Peru and Mexico in 2008, but decreased drastically in 2009–2011 due to the migration of giant squid to the south as a result of changes in water temperature (Figure 2.13). When the resource returns, the production should resume in the coming years with higher quality product resulting from pH-shift technology.

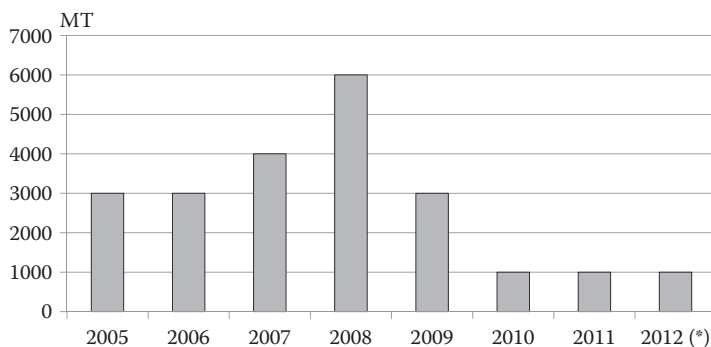


FIGURE 2.13 Surimi production from giant squid, 2005–2012. * Indicates estimated number.

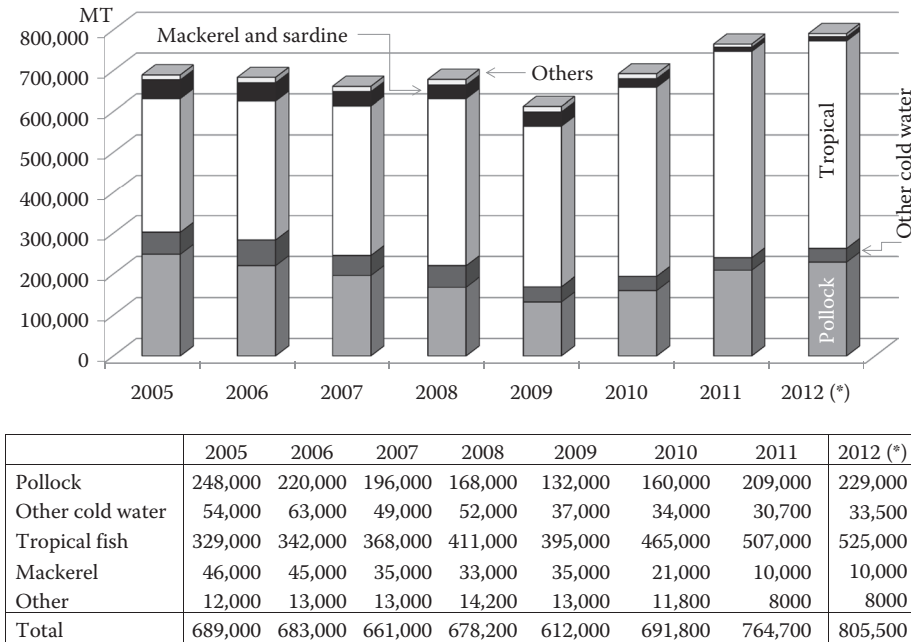


FIGURE 2.14 Global surimi production, 2005–2012. * Indicates estimated number.

2.6 GLOBAL SURIMI PRODUCTION TREND

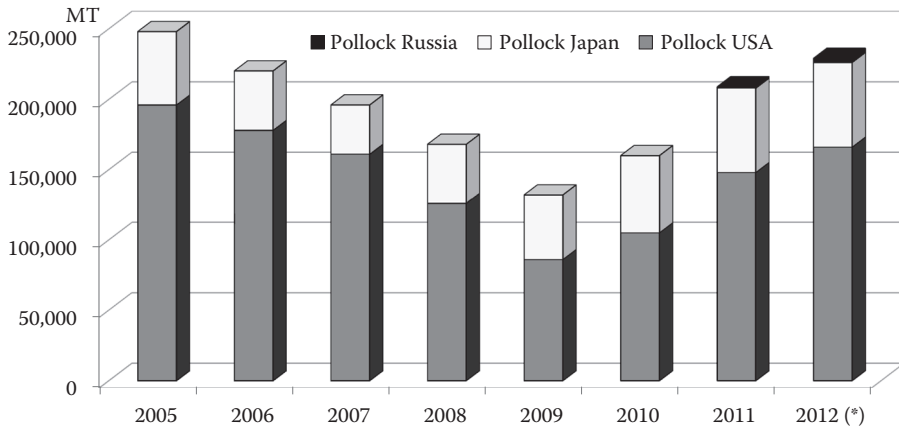
Surimi production over the last decade has been close to 700,000 MT and fairly stable. However, in 2009 production decreased to less than 600,000 MT as pollock surimi production hit a low due to a quota reduction in Alaska. In addition, Asia production was also at a record low following the economic crisis of 2008 in Asia. Since 2009, production continuously increased to reach near 800,000 MT in 2012 (Figure 2.14).

During that same time period some products faced large shifts in production volume. Alaskan pollock surimi production varied from 132,000 to 250,000 MT (Figure 2.15). Other cold water white fish surimi varied from 63,000 to 26,000 MT (Figure 2.16) and Mackerel surimi production dropped from 46,000 to 10,000 MT. Tropical fish surimi production, however, continuously grew during that period (except for 2009) to follow the increasing demand. The increased production of about 2–3% per year in average has been sufficient to cover the demand.

2.7 GLOBAL SURIMI MARKET

The world surimi seafood market was estimated at around 2 million MT of finished products in 2010, corresponding to a consumption of about 750,000 MT of raw material (Figure 2.17). This market is growing by 2–3% per year, particularly in South-East Asia and China.

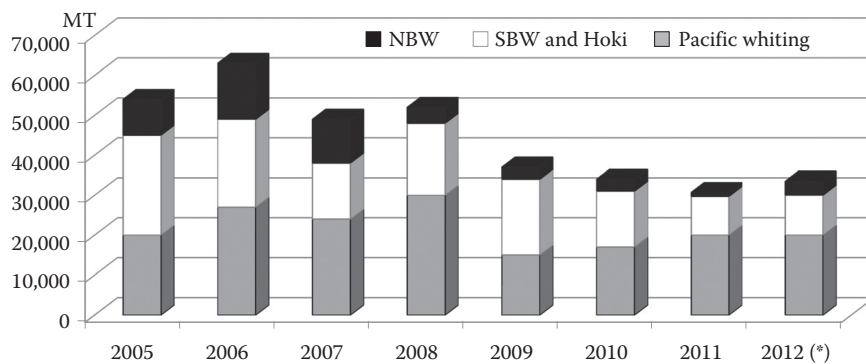
- With an annual consumption of 320,000 MT and a market for surimi products of 570,000 MT Japan still represents nearly 40% of the world surimi market.
- Korea consumes around 110,000 MT to process approximately 300,000 MT of fried products (ahmook) and crabstick production.
- Southeast Asia is estimated to use 80,000 MT of surimi to produce 160,000 MT of products, half of which is produced in Thailand, followed by Malaysia, Singapore, and Taiwan.



	2005	2006	2007	2008	2009	2010	2011	2012 (*)
Pollock USA	196,000	178,000	161,000	126,000	86,000	105,000	148,000	166,000
Pollock Japan	52,000	42,000	35,000	42,000	46,000	55,000	60,000	60,000
Pollock Russia	0	0	0	0	0	0	1000	3000
Total pollock	248,000	220,000	196,000	168,000	132,000	160,000	208,000	226,000

FIGURE 2.15 Surimi production from Alaska pollock by country, 2005–2012. * Indicates estimated number.

- Chinese surimi demand is over 200,000. The main usage is for fish ball and Asian style surimi products, such as dim sum, fried products, and fish-meat balls. The market for any products made with surimi was estimated to be over 1 million MT in 2011.
- Europe uses over 70,000 MT of surimi to produce 210,000 MT of surimi seafood products divided 50:50 between Eastern and Western Europe. The main market in Eastern Europe is Russia (80,000 MT) while Ukraine (15,000 MT) and Belarus (5000 MT) are also large markets for surimi seafood products. In Western Europe, the largest market is France (60,000 MT) followed by Spain (40,000 MT).



	2005	2006	2007	2008	2009	2010	2011	2012 (*)
Pacific whiting	20,000	27,000	24,000	30,000	15,000	17,000	20,000	20,000
SBW and Hoki	25,000	22,000	14,000	18,000	19,000	14,000	9700	10,000
NBW	9000	14,000	11,000	4000	3000	3000	1000	3500
Total	54,000	63,000	49,000	52,000	37,000	34,000	30,700	33,500

FIGURE 2.16 Surimi production from other cold water species, 2005–2012. * Indicates estimated number.

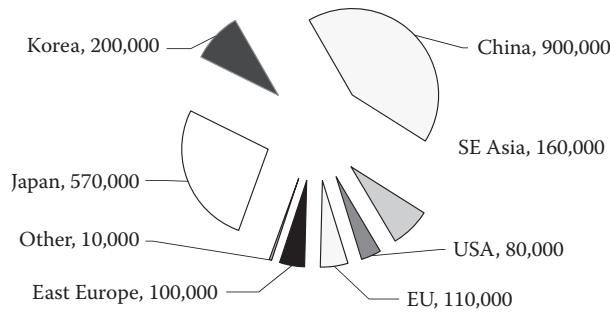


FIGURE 2.17 Surimi seafood production by region. Estimated 2 million MT in 2010.

- North America represents a market of over 30,000 MT of surimi used to produce 80,000–85,000 MT of crabstick and crabmeat (flakes). It has been considered a mature market since the 1990s (refer to Figure 1.5).

Market development of surimi seafood by country is described in depth in Chapter 1.

2.7.1 JAPAN

Surimi was first developed in Japan as a way to extend shelf-life of fish products. Surimi has been a traditional product in Japanese food for more than a century. The Japanese Surimi Seafood Industry includes large companies as well as numerous artisanal shops. A variety of surimi types are used to process over 1000 different products. Surimi seafood categories in Japan are defined by the cooking method: Steaming (kamaboko, crabstick), baking (chikuwa), frying (agemono or tempura), or boiling (hanpen, fish ball, fish sausage).

The Japanese surimi seafood market reached a maximum, with over 1 million MT consumption, in 1974–1976. The market has since declined as the Japanese younger generations turned to more western food and meat products. After years of continuous decline, the market finally has stabilized since 2010 at around 570,000 MT; including 500,000 MT of “traditional” surimi products and 70,000 MT of fish sausage/fish ham (refer to Figure 1.4).

Fish sausage was developed in the 1960s as a substitute for meat, which, at the time, was expensive. Fish sausage became a popular product and the market reached 180,000 MT in 1972. The volume later decreased, as did other surimi products. However, since fish sausage is cheaper than traditional surimi products it has recently regained interest from consumers.

For the production of all surimi seafood and fish sausage, Japan is using around 320,000 MT of surimi per year (40% of the world production); 80% of this volume is imported from all processing countries.

2.7.2 KOREA

Surimi is also a traditional product in Korea. Total production is estimated at approximately 300,000 MT, half of which is processed by small manufacturers. The leading product is fried surimi seafood, called ahmook, which is processed both by large factories as well as many small shops all over Korea. These products are made from low gel surimi imported mostly from Vietnam and China. In recent years, Korea developed high-quality crabstick, primarily with Alaska pollock surimi, and this market has been growing steadily. Premium crabsticks are often consumed as a snack while low-grade crabsticks are often used in gihmbahp (a Korean style roll wrapped with dried sea veggies). Fish sausage, hot bar, or other Japanese-style surimi seafoods are also popularly consumed.

Almost all surimi used in Korea is imported (110,000 MT) since the Korean factory trawlers lost access to Russian fishing grounds.

2.7.3 CHINA

Surimi products appeared in the northern part of China (Shandong Province) in the late 1980s for the export markets in the form of crabsticks using Japanese and Korean technology. The producers also developed the domestic market for these products. However, this business was significantly damaged because of the poor quality products that resulted from excessive price competition. Consequently, these low-quality products had a negative impact on Chinese customers and they began to avoid crabsticks.

Fish balls originated in China, but did not become expansively popular until the early 2000s, when processors in the southern part of China started develop this market. The market then increased at double-digit rates and spread throughout China. Fish balls are the primary surimi seafood in China and its market is estimated at over 300,000 MT. Besides the fish ball, a number of products are made with surimi (in low percentage): Fish-meat balls, fried products, or dim sum. The total market of surimi products was reported to be 960,000 MT in 2010 by *China Aquatic Journal*, the official journal of China Fishery Bureau, and this market continues to grow (refer to Figure 1.9).

Even though China continued its surimi production for domestic demands and exports to Korea and Japan, its production could not keep up with the domestic demand by 2010. Consequently, in 2011 China became a significant importer of surimi. The surimi market demands mostly low grade for domestic products and the main supplier is Vietnam. But China also imports a small volume of high-grade surimi, including Alaska pollock for crabsticks exported to Europe, the United States, and Japan.

Chinese surimi seafood production and surimi imports should continue to grow significantly in the coming years. In addition, surimi production from freshwater fish (aquaculture) is likely to increase in response to domestic demand.

2.7.4 SOUTHEAST ASIA

Surimi seafood was established in Southeast Asia in the most developed countries first: Hong Kong and Taiwan for Dim sum style products and Singapore for fish balls. Thailand and Malaysia also developed their markets based on traditional products, such as fish balls, fish cakes, and crabsticks, which were initially designed mostly for export. Southeast Asia is estimated to use 80,000 MT of surimi to produce over 200,000 MT of surimi seafood products. Half of this volume is processed in Thailand while Malaysia, Singapore, and Taiwan are also large producers. Many Asian style products also use surimi as an ingredient and were developed in Chinese descendent communities (dim sum, etc.).

Thailand uses about half of its surimi production for its domestic market for local consumption and the other half for surimi seafood products to be exported. Malaysia, Singapore, and Taiwan mostly process surimi products for their domestic markets.

Southeast Asia markets are growing steadily, especially for Asian style surimi seafood such as fish balls, fried products, and dim sum. It can be expected that these products will spread throughout Southeast Asia and result in a growing demand for surimi raw material in this region.

2.7.5 NORTH AMERICA

Surimi products were brought to America as “imitation crabmeat” by importers in the late 1970s. The surimi crabmeat products were a cheaper and convenient substitute to crab meat, which was in short supply at the time. The production of “crabsticks” started in the 1980s. The market then grew rapidly and reached maturity in the 1990s with a total market estimated at around 85,000 MT of products (refer to Figure 1.5). In particular, the U.S. market’s main product is “crab meat”

(a crab-flavored product cut in flakes) that is used as an ingredient in salads, sandwiches, and ready meals. More than 50% of the sales are to the food service segment and frozen/chilled products co-exist in the market. U.S. processors use almost exclusively the local resource of Alaska pollock and Pacific whiting surimi for their surimi products.

2.7.6 WESTERN EUROPE

Surimi products were also introduced to Europe in the late 1970s and in the 1980s in the form of crabsticks imported first from Japan and later from Korea, Thailand, and China. The first producers for these products appeared in France in the late 1980s and production rapidly grew in the 1990s and 2000s to reach 60,000 MT by 2010 (refer to Figure 1.6). During the 1990s, production expanded into Spain, Italy, and Lithuania. Spanish producers developed a special product for their market with “angulas” (baby eels), which replaced the popular, natural counterpart in the Basque country. Another product popular in Spain is breaded crab claws (called “muslitos”). The sale of surimi products spread throughout Europe, mostly in the form of crabstick, which reached a volume of over 100,000 MT by 2010.

The surimi raw material is mostly imported (with the exception of a small production of Northern blue whiting surimi by a French vessel). Alaska pollock dominates the market and represents over 50% of the total market. Processors also use Pacific whiting, hoki, and threadfin bream surimi. One particularity of the European market in the 2000s was the large volume of jack mackerel surimi (30% of the total imported volume) used for crabstick production in order to lower the cost of raw material. When this resource disappeared in 2006–2007, processors substituted this surimi with low-grade Alaska pollock and low-grade tropical fish surimi mostly from Vietnam.

2.7.7 EASTERN EUROPE AND RUSSIA

Surimi seafood production appeared in the Soviet Union in the early 1980s with machinery imported from Japan to process crabsticks. This small-scale production practically disappeared after the collapse of the Soviet Union and was replaced with imports from Korea and China in the 1990s. But in the mid-1990s, several companies resumed production with modern equipment, and local manufacturers now dominate the market with a production of about 100,000 MT of products (mostly crabsticks). About 80% is processed in Russia while Ukraine and Belarus are also processing these products (Figure 2.18).

These markets have been dominated by low-quality products and declined since the mid-2000s. However, when the main market players started promoting higher quality chilled products, which were well received by the market, this trend was reversed.

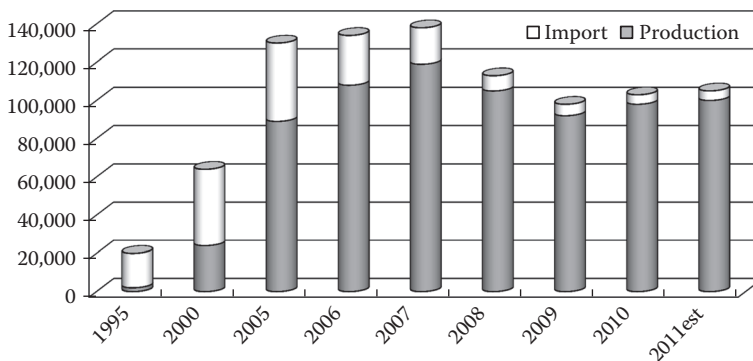


FIGURE 2.18 Trend in Eastern European surimi seafood production and imports, 1995, 2000, 2005–2011.

2.7.8 SOUTH AMERICA

Surimi seafood in South America was first developed in Argentina in the 1990s in the form of crabstick using Japanese technology. Later, some factories were built in Uruguay, Peru, and Brazil. However, most of these have been unsuccessful due to the slow development of the market and the economic instability of the region. The small market is dominated by products imported from China.

2.8 CONCLUSIONS: CHANGES IN SURIMI SUPPLY AND DEMAND

Surimi production worldwide reached around 800,000 MT by 2011–2012. Production has remained fairly stable in the last decade with the main fluctuations resulting from variations of fishing quotas (Alaska pollock, Pacific whiting, jack mackerel, SBW, and Northern blue whiting) while production from tropical fish in Southeast Asia has been steadily growing (with the exception of the year 2009 when production was low as a result of the economy crisis of 2008).

Cold water surimi production is around 250,000 MT, dominated by Alaska pollock (220,000 MT production in 2012) while other coldwater white fish surimi (Pacific whiting, hoki, SBW, and Northern blue whiting) represent less than 30,000 MT. Less than half of this production is high-grade surimi (SA, FA, and A), most of which is sold to Japan for kamaboko and other high quality surimi products. High-grade surimi is also used for premium crabsticks in Korea. Lower grades (KA, KB, and RA) are sold to the United States and Europe for crabstick production and Japan and Korea for fried products.

Surimi production from pelagic fish, such as jack mackerel and atka mackerel has greatly decreased (since mid-2000s when these productions reached 45,000 MT) due to the reduction of fishing and high demand for these fish for whole fish consumption in emerging markets (particularly West Africa). However, tropical fish surimi production is over 500,000 MT, most of which is used in Asia (Japan, China, Korea, Southeast Asia) where the main markets include fish balls and fried surimi products.

Technological advances in surimi processing have allowed the use of lower grade surimi in various surimi seafood products. This is especially true in Southeast Asia and China. These markets are growing and tend to use low grades of surimi for manufacturing fish balls, fish cakes, and other surimi products. The decline of the Japanese market, on the other hand, has resulted in a lower demand of high-grade Alaska pollock and other cold water white fish surimi. The increasing cost of fishing due to high oil prices (and the high price for fish feed used in aquaculture) has resulted in higher production costs for surimi around the world. Consequently, a demand for inexpensive surimi seafood drives the surimi seafood industry to a difficult situation.

As the demand for surimi continues to grow, especially for cheap, low-grade surimi, new species should appear in the market. New processing methods such as the pH-shift method (see Chapter 6) also have the potential to increase the use of new species, like giant squid and small pelagic species, and improve recovery from traditional species. Surimi from giant squid in the South Pacific (Peru) is a new product that could be developed in the coming years. Surimi from aquaculture fish, such as carp and catfish (*Pangasius*), should also grow in response to increased demand.

Overall, the surimi industry is not suffering from a lack of resources rather it faces challenges in terms of production cost and competition from other usage of fish for human consumption. Surimi seafood consumption continues to grow, particularly in Southeast Asia and China where surimi products have found their niche as inexpensive fish products, thus requiring large volumes of cheap raw materials. As the world fish consumption continues to grow, the convenience of surimi seafood (easy to process, easy to store, easy to eat, adapted to mass production) makes it a perfect product to face the challenges of the world food demand of the twenty-first century.

ACKNOWLEDGMENTS

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