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An Assessment on Harvest, Exports, and Marketing Income Relationships of Freshwater Crayfish in Turkey

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ABSTRACT

This study analyzes the export and international trade status of freshwater crayfish (*Pontastacus leptodactylus*), which is an important export product and economic value in Turkey, by simulating the future with the last 10 years (2014-2023) data. The data set shows how and to which countries crayfish are offered as an annual product and in what quantities. Turkey exports an average of 440.364 kg of canned crayfish per year. With an average unit price of $10.12 per kg, Turkey earns USD 4.458,809. Turkey exports 51.268 kg of freshwater crayfish meal, paste, and pellets worth USD 338,926 with an average unit price of USD 6.61 per kg. In addition, the average annual export volume for frozen or live crayfish is 42.327 kg valued at USD 163,509, with an average unit price of USD 3.86 per kg. Turkey's main export destination for crayfish products is Sweden (about 70%) with an average annual export volume of 390.252 kg valued at USD 41.231,013 and an average unit price of USD 10.56 per kg. Other important export countries include Russia (790.887 kg, USD 3.116,688, USD 3.94 per kg), Moldova (135.146 kg, USD 706.339, USD 5.23 per kg) and Belgium (111,509 kg, USD 791.811, USD 7.10 per kg). The United States of America also has a high unit price of USD 12.35 per kg with an export volume of 65.783 kg valued at USD 812.253. The important points that stand out in this study are that while there is no significant increase in quantity, there are significant increases in income over the years depending on product diversity. Sweden stands out in Turkey's exports in this respect. Due to the increasing demand for frozen and processed products due to the COVID-19 pandemic between 2019-2020, it is thought that the highest exports are in these years. The analysis using the ARIMA model showed significant fluctuations in annual export volumes and values, but an overall positive trend was identified. The study highlights the importance of promotional activities to increase domestic consumption and the need to optimize harvesting practices. Turkey's freshwater crayfish exports have growth potential due to increasing global demand and expanding production capacity. As a result, it is thought that crayfish, which provides a significant foreign currency inflow to Turkey, can provide higher economic benefits by increasing product diversity.

Keywords: Crayfish, Trend analysis, Economic income, Export, Turkey.

1. INTRODUCTION

As the world's population increases, the importance of nutrition and animal proteins in the diet becomes more apparent. Consumers seek foods to be safe, nutritious, easy to obtain when desired, convenient to use, and attractive in taste and appearance. For this reason, the seafood

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market, which is at the forefront of foods containing high levels of high-quality protein, is gaining importance with each passing day (Tso et al., 2021). Crustacean and arthropod aquaculture products are popular and fetch high prices. Crayfish, which are extremely valuable food and an integral part of a balanced diet, are widely available in the waters of our country, are in great demand, especially in European countries, and are among the aquaculture products exported by Turkey (Erençin and Köksal, 1977; Aydın et al., 2012; Aydın, 2013; Aydın et al., 2015; El-Sherif and El-Ghafour, 2015; Kale and Berber, 2020) (Table 1). Over the years, the crayfish market has extended, and this situation made crayfish a valuable food source for humans. Thus, the formation of a traditional consumption culture in many European countries has increased the commercial value of the species (Ackefors, 2017).

Crayfish, refer to freshwater crustaceans that live in swamps, rivers, and lakes, are an important component of the stream ecosystem (Erençin and Köksal, 1977; Balık et al., 2006; Akhan et al., 2014; Mazlum et al., 2019; Korkmaz et al., 2022; Benzer and Benzer, 2024). They have a rigid exoskeleton, compound eyes, a compound head and thorax, a pointed snout, and a segmented body in a variety of colors such as sandy yellow, dark brown, green, blue and red (Avsever, 2008; Kale et al., 2020; 2021). Crayfish meat is extremely popular due to its soft texture, delicious taste, and good source of protein (Berber and Balık, 2006; Mazlum and Yilmaz, 2006; Sun et al., 2023; Dobrzycka-Krahel et al., 2024). Crayfish are rich in various mineral elements and vitamins for human health, such as sodium, potassium, magnesium and selenium (Peng et al., 2021; Mazlum and Uzun, 2022; Shen et al., 2024). They also have a favorable fatty acid composition containing about 50% unsaturated fatty acids, including amino acids, eicosatetraenoic acid (EPA), and docosahexaenoic acid (DHA), which are essential for humans (Oksuz and Mazlum, 2016; Śmietana et al., 2020; Li et al., 2021; Berber et al., 2024). In addition, crayfish are also used in fish and animal feeds as a source of mineral matter for waste that is not human food (Mazlum, 2023). Approximately 100,000 tons of crayfish shells are produced worldwide, and the wastes generated during the processing of crayfish typically range from 40% to 50%, of which 40% is chitin (Peng et al., 2016; Cai et al., 2017). Crayfish shells contain significant proportions of protein, calcium carbonate, chitin (20 to 30%), omega-3 fatty acids, pigments, and other minerals, making them suitable for various industrial applications (Vicente et al., 2022). The processability of crayfish allows the market to develop in remote areas where they are not produced.

According to the crayfish market analysis, global interest in gastronomy in recent years has brought about a boom in the status of crayfish. The growth of food tourism and culinary experiences has exposed more people to the exquisite taste of crayfish, which has contributed

to an increase in demand (Okeke and Nwankwo, 2020). Crayfish meat is recognized as an important and expensive food source for people in the USA, China, and most European countries (El-Sherif and El-Ghafour, 2015). International trade is considered the driving force of global economic progress and exports between countries are considered as the exchange of goods and services (Helpman, 2011). Earnings from exports significantly impact on a country's economic growth (Rahman et al., 2019). Therefore, the export-led growth hypothesis has attracted considerable attention from scholars (Choi, 2010; Eaton et al., 2011; Herrerias and Orts, 2010).

According to FAO (2022) data on global aquaculture production, a total of 182,777,048 tons of production was achieved in 2021. Of this, 91,913,341 tons came from harvesting, while 90,863,706 tons were from aquaculture. Crustaceans contributed to this production with 11.88 million tons (9.4%). The total production value was 296.03 billion US dollars. The size of crayfish production in the global market reached 10.32 billion US dollars, with a growth of 16% according to 2023 data. Total aquaculture production in Turkey is 800 thousand tons as of 2021. Of the total production, 328 thousand tons were obtained from harvesting, and 472 thousand tons from farming. In production, the rate of hunting is 41% and farming is 59% (TurkStat, 2022). Of the total commercial value of aquatic products with a total commercial value of 424 billion US dollars, 143 billion dollars are obtained from catching and 281 billion dollars are obtained from aquaculture (FAO, 2022).

Crayfish is one of the materials contributing to the global export market. Many governments promote crayfish production by providing fiscal incentives and tax exemptions to increase export revenues and minimize import dependency (Rivera-Ferre, 2009; Esheya, 2023). The market is driven by rising income levels and increasing demand for crayfish and similar products among consumers worldwide (de Abreu et al., 2010; Ele and Nkang, 2014). Crayfish production shows a continuous growth trend in Turkey as well as in the world. In Turkey, crayfish are exported in three different forms: canned, frozen, and fresh. While some countries buy crayfish in these three different conditions, some countries buy crayfish only unfrozen and some only canned. Crayfish can also be purchased live from retailers or directly from producers. Abdominal meat has better usable and processable properties when compared to live crayfish (Romaire et al., 2005). Crayfish meat can be packaged with or without the hepatopancreatic tissue, which has a fatty structure. The most common processing method is cooking, although manual shelling is also used. Depending on regional preferences, crayfish are consumed and cooked with different vegetables. Many crayfish processing companies add some additives to fresh or processed products to improve preservative and sensory properties.

Although crayfish has long been a staple in the kitchens of regions such as Louisiana in the United States, it is now making its way onto dinner tables around the world. Crayfish is a popular food in China. Crayfish can reproduce throughout the year, with the peak of reproduction occurring from May to September, with domestic sales and exports in the People's Republic of China reaching two million tons. Turkey production is far below this figure. In addition, the crayfish species grown in Turkey differs from the crayfish of other countries in the world. While crayfish of the genus *Astacus Astacus* are grown in Europe, *Pontastacus leptodactylus* stands out in Turkey and Eastern Europe. In Far Eastern countries, crayfish of the genus *Procambarus* are cultivated. Crayfish produced in Turkey generally find more buyers in Eastern European countries and Russia. According to the China Crayfish Industry Development Report 2023, China's crayfish production continued to increase in 2022. The high production has increased the wide availability of the product in the region. The Global Crayfish Market reached USD 15.4 billion in 2023.

This study aims to investigate the export competitiveness and its trend analysis of freshwater crayfish (*Pontastacus leptodactylus*), an important export product and economic value in Turkey, between 2014-2023. In addition, within the scope of this study, how and how much crayfish are offered to which countries as an annual product, and what can be done to increase exports are discussed.

2. MATERIAL AND METHODS

2.1. Data collection

In this study, data on crayfish exports from Turkey were obtained from the Turkish Statistical Institute (TurkStat) database for the period 2014-2023. The dataset includes detailed information on export quantities (in kilograms) and values (in USD) for different product types of crayfish, canned, frozen, and live, fresh or chilled freshwater crayfish.

2.2. Data analysis

The data covers the evaluation of the export and international trade status of freshwater crayfish (*Pontastacus leptodactylus*), which is an important export product and economic value in Turkey. The data set includes export quantities and values classified by year, product type and destination country. Export quantities values were converted from kilograms to tons by dividing by 1,000. Export values were converted from USD to millions of USD divided by 1,000,000. For each product type, the percentage changes in export quantities and values from year to year were calculated. Since the data includes a time dimension, the percentage change for a specific

year in the analysis of export quantities was calculated with the help of the following formula. This calculation provides a forecast of annual growth or decline in export performance.

$$\text{Percentage Change} = \frac{\text{Current Year Value} - \text{Past Year Value}}{\text{Past Year Value}} \times 100$$

The data obtained from this study were analyzed using various tools and techniques. Quantitative analytical techniques were used to achieve the objectives. It was analyzed using descriptive statistics and statistical tools such as means and percentages. Regression analysis was used in the relationship between harvest, income and exports. For data analysis, three main product types were focused on. These are canned, frozen, and live, fresh or chilled freshwater crayfish, respectively. For each product type, the ARIMA model for trend analysis was used to determine annual export volumes and values, and to identify significant trends, fluctuations and overall performance over the period from 2014 to 2023. Line graphs in this study were created to visualize the annual percentage changes in export volumes and values for each product type. These graphs facilitated the identification of trends and patterns over the years. Tables were also created to present the annual export quantities and values with their percentage changes.

3. RESULTS

Most of the crayfish harvest in Turkey is exported to many European countries. In recent years, Sweden, Russia, China, Belgium, Israel, Germany, and the Netherlands have been the largest exporters of crayfish. Turkey's total crayfish exports between 2014 and 2023 were 485.656 kg, of which 390.3 kg (80.41%) were exported to Sweden alone (Table 1). Crayfish are exported in three different forms: canned, fresh, and frozen. While some countries buy crayfish in these three different conditions, some countries buy crayfish only unfrozen, and some only canned. Turkey's total crayfish exports between 2014 and 2023 are 485.656 kg and the total commercial value of crayfish for these years is 6.97 million US dollars (Table 1, Figs 1 and 2).

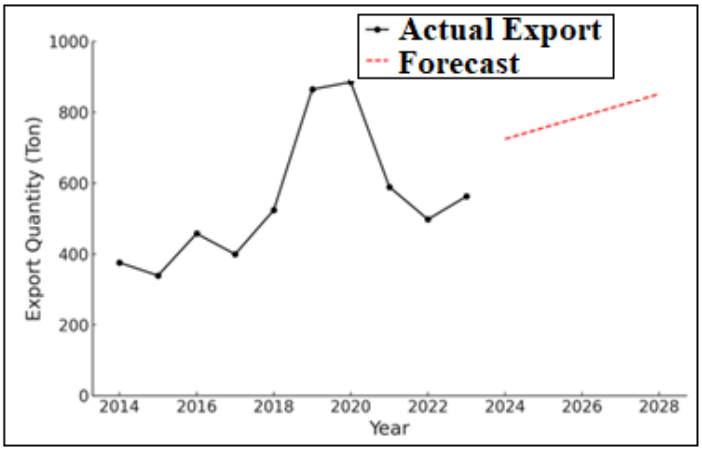

Figure 1. Freshwater crayfish export amounts in Turkey by years (tons).

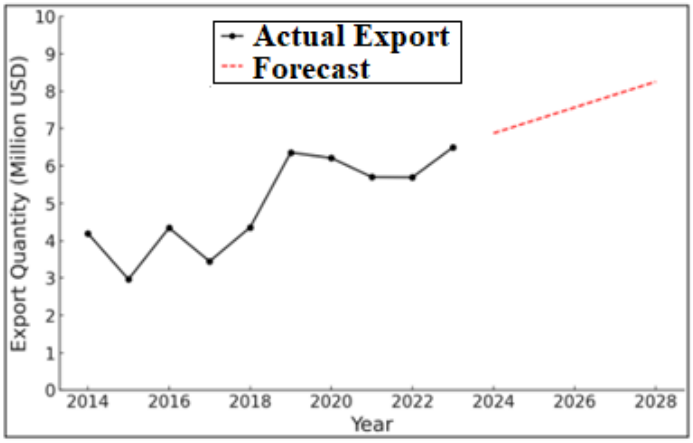

Figure 2. Export values of freshwater crayfish in Turkey by years (million US dollars).

Table 1. Country-wise distribution of Turkey's crayfish exports over the past decade.

Country	***Annual Export Amount (tons) ± SE***	***Annual Export Value (million USD) ± SE***	***Unit Price (USD/ton) ± SE***
Sweden	390.3 ± 24.8	4.1 ± 0.3	10.6 ± 0.4
Russian Federation	43.9 ± 21.2	0.2 ± 0.1	3.9
China	14.0 ± 7.5	0.0 ± 0.0	3.2 ± 0.8
Belgium	12.4 ± 3.5	0.1 ± 0.0	7.1 ± 8.7
Israel	11.7 ± 4.6	0.1 ± 0.0	8.4
Georgia	10.6 ± 4.0	0.0 ± 0.0	2.4 ± 0.8
Moldova	9.7 ± 2.9	0.1 ± 0.0	5.2 ± 42.2
South Korea	8.7 ± 4.8	0.0 ± 0.0	4.9 ± 2.2
Germany	8.6 ± 5.2	0.1 ± 0.0	8.2
Netherlands	6.8 ± 4.3	0.1 ± 0.0	8.4
USA	5.5 ± 1.7	0.1 ± 0.0	12.4 ± 11.4
Ukraine	4.9 ± 1.9	0.0 ± 0.0	5.1 ± 7.5
Greece	4.0 ± 2.0	0.0 ± 0.0	7.5 ± 9.4
Italy	3.4 ± 1.2	0.0 ± 0.0	8.5
Luxembourg	2.7 ± nan	0.0 ± nan	6.6
Romania	1.4 ± 1.3	0.0 ± 0.0	12.2 ± 32.2
Philippines	0.9 ± nan	0.0 ± nan	4.5
France	0.7 ± 0.5	0.0 ± 0.0	48.5
Albania	0.4 ± 0.0	0.0 ± 0.0	77.7 ± 14.1
Bulgaria	0.4 ± 0.4	0.0 ± 0.0	10.4
Hong Kong	0.2 ± nan	0.0 ± nan	0.1 ± nan
Czech Republic	0.2 ± 0.1	0.0 ± 0.0	7.3 ± 6.4
Northern Cyprus	0.1 ± 0.1	0.0 ± 0.0	4.1 ± 0.9

***Note**: *nan: Not a Number.*

Figures 1 and 2 show the amount and value of Turkey's crayfish exports from 2014 to 2023. The period from 2024 to 2028 shows the estimated situation in export amounts using the ARIMA method. In terms of export amounts (Fig 1), there have been significant fluctuations over the last decade. For example, Turkey exported approximately 375.461 kg of crayfish in 2014. This export amount decreased to 339.185 kg in 2015 but recovered again in 2016 and

increased to 457.555 kg. The export amount continues to increase and reached its peak in 2018 with 523.483 kg. However, there were some declines in the following years. By 2023, it is seen that exports had generally increased again, reaching 485.656 kg.

The ARIMA model predicts that Turkey's crayfish exports will reach approximately 1,000 tons in 2028. This positive trend indicates that Turkey's crayfish export sector could potentially experience growth due to increased global demand and increased production capacity. In 2014 (Fig 2), Turkey's crayfish exports were worth approximately 4.19 million dollars. This value decreased to 2.96 million dollars in 2015 but increased again to 4.34 million dollars in 2016. The highest value recorded was in 2018, with exports of approximately 4.36 million dollars. Although there were fluctuations, export values remained relatively high at 4.13 million US dollars in 2023. The forecast for export values from 2024 to 2028 shows a gradual increase in parallel with the projected increase in export amounts. According to these estimates, the export value is expected to reach around 6 million dollars in 2028. This expected growth in export values indicates a positive outlook for the Turkish crayfish industry, driven by positive market conditions and potential improvements in export strategies.

Table 2. Export amount and value of canned crayfish from Turkey for the last decade.

Year	***Export Quantity (Tons)***	***Export Value (Million USD)***	***Quantity Change (%)***	***Value Change (%)***
2014	317.89	3.78	nan	nan
2015	289.17	2.68	-9.04	-29.11
2016	412.48	4.03	42.64	50.29
2017	270.20	2.90	-34.49	-27.97
2018	408.75	3.87	51.28	33.26
2019	538.13	4.80	31.65	24.17
2020	445.38	4.49	-17.24	-6.46
2021	459.06	4.80	3.07	6.82
2022	450.41	5.15	-1.88	7.28
2023	477.49	5.68	6.01	10.44

***Note**: *nan: Not a Number.*

There were significant fluctuations in the export volumes and values of canned crayfish between 2014 and 2023 (Table 2). In 2014, Turkey exported 317.90 tons of product worth USD 3.78 million. The following year, 2015, saw a decline in both quantity and value, with exports falling by 9.04% and 29.11% to 289.17 tons and 2.68 million USD, respectively. In 2016, there was a significant recovery, with export volumes up 42.64% to 412.48 tons and value up 50.29% to USD 4.03 million. In 2017, however, volumes fell by 27.97% to 297.20 tons and value by 27.97% to US$ 2.90 million. In 2018, exports increased by 33.26% to 396.09 tons worth USD

3.87 million. This positive trend continued in 2019, with volumes increasing by 31.65% to 538.14 tons and value by 24.17% to USD 4.80 million (Table 2).

In 2020, volumes fell by 17.24% to 445.38 tons and values by 6.46% to US$4.49 million. This was followed by moderate growth in 2021, when volumes increased to 459.06 tons (up 3.07%) and values rose by 6.82% to USD 4.80 million. In 2022, export volumes declined slightly (down 1.88%) to 450.41 tons, but values increased to US$ 5.15 million (up 7.28%). Finally, in 2023, exports recovered, increasing by 6.01% in quantity to 477.49 tons and by 10.44% in value to US$ 5.68 million (Table 2).

Table 3*. Export Amounts and Value of Frozen freshwater crayfish from Turkey between 2016 and 2023.*

Year	Export Quantity (Tons)	Export Value (Million USD)	Quantity Change (%)	Value Change (%)
2016	0.00	0.00	nan	nan
2017	56.72	0.16	inf	inf
2018	38.61	0.01	-31.93	-96.37
2019	42.69	0.24	10.56	4079.23
2020	2.69	0.01	-93.71	-97.01
2021	19.16	0.07	613.22	898.48
2022	4.69	0.15	-75.51	113.33
2023	25.36	0.20	440.56	34.74

Note*: *nan: Not a Number; inf: infinity.*

Frozen freshwater crayfish exports started in 2016 with a modest volume of 0.07 tons and a value of USD 0.0021 million. In 2017, there was a slight decrease to 0.005 tons and a small increase in value to USD 0.0055 million. In 2018, there was a significant increase in both quantity and value, with exports reaching 0.25 tons (up 4900.00%) and US$ 0.018 million (up 223.67%) (Table 3). This positive trend continued dramatically in 2019, with volumes rising to 42.69 tons (up 16975.20%) and values rising to US$ 0.24 million (up 1229.84%). In 2020, however, there was a sharp decline, with volumes down 93.71% to 2.69 tons and values down 97.01% to US$ 0.007 million (Table 3). In 2021, exports increased again, reaching 19.16 tons in quantity (up 613.22%) and US$ 0.070 million in value (up 898.48%). The following year, 2022, saw a significant drop in volumes (down 75.51%) to 4.69 tons, but values increased to US$ 0.150 million (up 113.33%). In 2023, volumes increased by 440.56% to 25.36 tons and values by 34.74% to US$ 0.202 million.

Exports of live, fresh or chilled freshwater crayfish started in 2017 at 72.36 tons valued at USD 0.389 million. In 2018, exports increased significantly to 76.12 tons (up 77.41%) and valued at US$ 0.484 million (up 24.30%). This trend continued with a sharp rise in 2019, with volumes reaching 284.04 tons (up 273.15%) and values reaching US$ 1.32 million (up

173.35%) (Table 4). In 2020, growth continued, with volumes increasing by 53.87% to 437.06 tons and values reaching USD 1.72 million (up 29.59%). However, in 2021, volumes fell by 74.63% to 110.90 tons and values by 51.33% to US$ 0.835 million. In 2022, the downward trend continued, with volumes falling further to 42.54 tons (down 61.64%) and values down to US$ 0.401 million (down 52.01%). In 2023, there was a recovery, with volumes increasing by 40.25% to 59.66 tons and values rising to US$ 0.614 million (up 53.19%) (Table 4).

Table 4. Export amounts and value of live, fresh, or chilled freshwater crayfish from Turkey between 2017 and 2023.

Year	***Export Quantity (Tons)***	***Export Value (Million USD)***	***Quantity Change (%)***	***Value Change (%)***
2017	72.36	0.39	nan	nan
2018	76.12	0.48	5.19	24.30
2019	284.04	1.32	273.15	173.35
2020	437.06	1.72	53.87	29.59
2021	110.90	0.83	-74.63	-51.33
2022	42.54	0.40	-61.64	-52.01
2023	59.66	0.61	40.25	53.19

***Note**: *nan: Not a Number.*

Table 5. Annual Average Unit Prices of Freshwater Crayfish Products from Turkey for the last decade (USD/kg).

Year	***Prepared or Preserved Crayfish***	***Ground or Pelletized Crayfish (Non-frozen)***	***Frozen Crayfish***	***Live, Fresh, or Chilled Crayfish***	***Dried, Salted, or Brined Crayfish***
2014	11.9	7.2	-	-	-
2015	9.3	5.7	-	-	-
2016	9.8	7.0	-	-	-
2017	10.7	-	2.7	5.4	-
2018	9.5	-	0.1	6.4	-
2019	8.9	-	5.5	4.7	-
2020	10.1	-	2.6	3.9	-
2021	10.4	-	3.7	7.5	4.4
2022	11.4	-	3.9	9.4	-
2023	11.9	-	7.9	10.3	-

When the distribution of canned crawfish exports between 2014 and 2023 is analyzed, it is determined that the export value is maintained in 2023, although fluctuations are observed between years. Exports of unfrozen crayfish showed significant fluctuations between 2014 and 2016. On the other hand, exports of frozen crayfish exhibited a continuous upward trend covering the years 2017-2023. Similarly, exports of live, fresh or chilled crayfish also show an upward trend between 2017 and 2023. Exports of dried, salted or pickled crayfish occurred only in 2021 (Table 5).

Table 6. Crayfish harvest, income, export and export income amounts in Turkey by year.

Date	***Harvest (Tons)***	***Income value (million USD)***	***Export (Tons)***	***Export income (Million USD)***
2000	1,681	3.846	758	3.592
2001	1,634	2.783	1,181	4.062
2002	1,894	4.583	726	3.905
2003	2,183	7.106	691	4.713
2004	2,317	6.819	845	5.721
2005	809	3.033	725	4.887
2006	797	3.209	164	1.661
2007	816	3.381	182	2.186
2008	783	3.366	305	2.931
2009	734	2.713	240	2.221
2010	1030	3.605	200	2.862
2011	610	2.255	229	2.708
2012	492	1.189	241	3.042
2013	532	1.888	316	4.243
2014	582	2.037	377	4.193
2015	532	2.036	339	2.964
2016	544	1.698	457	4.193
2017	669	2.074	399	3.445
2018	524	1.525	523	4.355
2019	696	1.895	864	6.358
2020	1,233	2.594	885	6.211
2021	1011	3.057	589	5.701
2022	662	2.758	497	5.695
2023	900	3.257	562	6.497

To analyze the table 6 in detail, we need to focus on a few key metrics and trends: harvest amount, income value, export amounts, and export value. By examining this data over the years, we can detect changes and possible relationships. The highest harvest was in 2004 with 2,317 tons, and the lowest harvest was in 2012 with 492 tons. The highest income value was recorded in 2003 with 7.106 million USD, and the lowest income value was recorded in 2012 with 1,189 million USD. There is not always a direct relationship between the amount of harvest and income value by year. For example, in 2005 the harvest was low at 809 tons, but the revenue value was moderate at US $3.033 million. In 2023, the harvest amount was 900 tons, and the income value was 3.257 million USD. The highest export amount was in 2020 with 885 tons, and the lowest export amount was in 2006 with 164 tons. The highest export revenue was in 2019 with 6.358 million USD, and the lowest export amount was in 2006 with 1.661 million USD. There is a stronger relationship between export quantity and export income. For example, the increase in export amounts in 2019 and 2020 led to an increase in export

revenue. Notable years include 2003, with high harvests (2.183 tons) and revenues (US $7.106 million), and 2012, with the lowest harvests (492 tons) and revenues (US $1.189 million). In 2019, export amount (864 tons) and export revenue (6.358 million USD) reached their peak (Figs 3 and 4). In general, increases in export volume tend to be associated with increases in export revenue. However, some years, such as 2020 and 2021, show high export revenue despite relatively low export amounts, indicating differences in product prices. During the period from 2000 to 2023, significant fluctuations in both harvest and export quantities were observed, possibly influenced by factors such as climatic conditions, market demand, price fluctuations and production conditions.

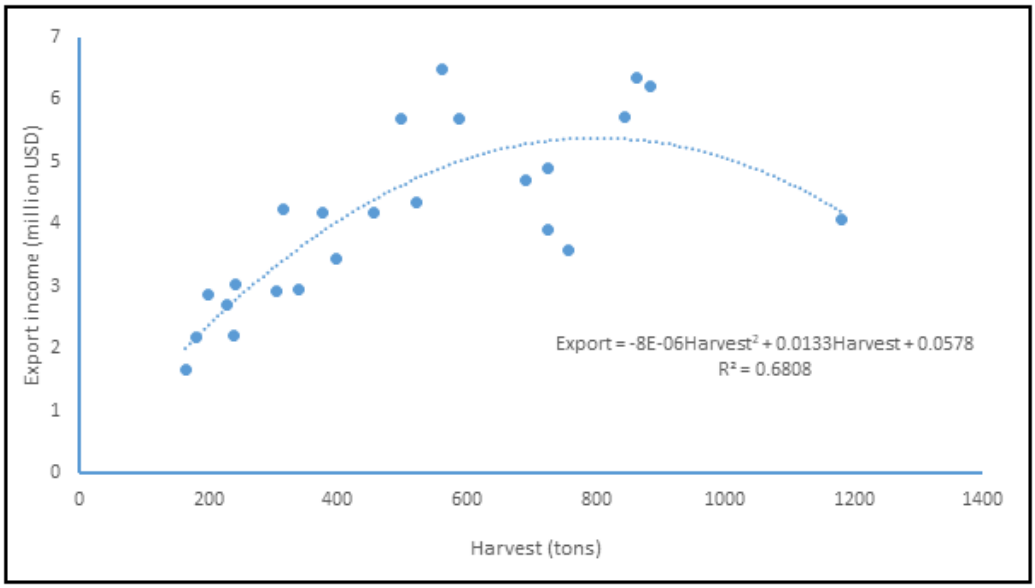

Figure 3. The relationship between crayfish harvest and the amount of export in Türkiye.

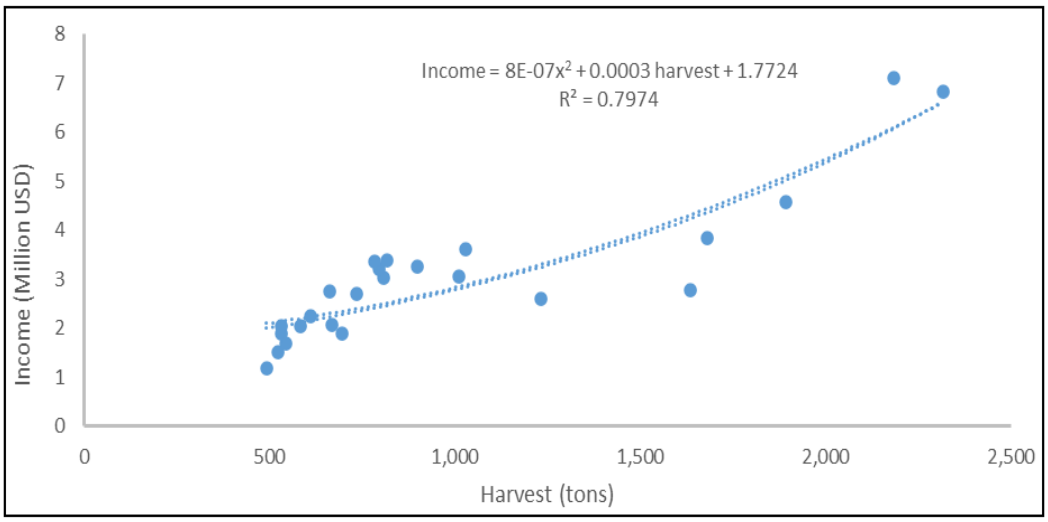

Figure 4. The relationship between crayfish harvest and income in Türkiye.

4. DISCUSSION

The Global Crayfish Market reaches USD 9.9 billion in 2022. The crayfish market refers to an economic ecosystem focused on the production, distribution, and consumption of crayfish, a freshwater crustacean. Widely consumed both in the kitchen and as feed, crayfish is prized for its tender meat and unique flavor, making it a sought-after delicacy in many cuisines across the globe. There are various stakeholders in this market, such as crayfish farmers, fishermen, seafood wholesalers, retailers, restaurants, and consumers. Türel et al. (2015) stated that Turkey has become the main market with more than 70 percent of the world crayfish market. The importance of crayfish in the food market is increasing due to factors such as consumer preferences, culinary trends, and cultural traditions. The crayfish market is subject to various drivers and challenges, including environmental regulations, sustainability concerns, technological developments, market competition, and economic factors.

The results of this study show that the economic value of canned, frozen and live crayfish has the potential to become a new food industry for domestic and external markets. Crayfish are seasonal and the harvest period depends on water, temperature and other natural conditions (Berber et al., 2011; Ölçülü et al., 2019). Since crayfish production in Turkey (Fig 4) is entirely based on fishing. These fishing activities are carried out for 4 months between July 1 and November 1. However, its transportation, marketing, export and processing is prohibited between November 1 and June 30, and this regulation is made by the Ministry of Food, Agriculture and Livestock. According to the regulation, it is forbidden to land crayfish smaller than 10 cm and crayfish smaller than 10 cm are released back into the water after being removed from the basket (MAF, 2020). Previous studies have indicated that inadequate catching of natural populations in Turkey has led to a steady decline in both the number of crayfish caught and the average size of crayfish supplied to the European market (Köksal, 1988; Skurdal and Taugbøl, 1994). On the other hand, Türkmen and Karadal (2012) noted that there is still not any management and controlling mechanisms that have been implemented for crayfish populations in Turkey. Moreover, Cılbız et al. (2020) stated that it would be beneficial for the Ministry of Agriculture and Forestry to make some arrangements in the communiqué so that the products resulting from catching gain more economic value.

The increase in animal protein prices in recent years has caused people with average incomes to turn to cheap protein sources such as crayfish and fish, which has led to an increase in demand for crayfish among the public (Simonyan, 2016). When we consider the crayfish exports for the years 2014-2023, it is seen that we sell crayfish to 23 countries. Sweden, Russia, China, Belgium, Israel, Germany, and the Netherlands account for the largest part of these sales.

When TurkStat statistical data are analyzed, it is seen that there is an irregular fluctuation (decrease and increase) in crayfish catch figures by years (Table 6).

The important point that stands out in this study is that while there is no significant increase in the number of crayfish harvested, there has been a crucial increase in income over the years due to product diversity. The increasing development of the crayfish industry and the increase in the variety of processed products increase the consumption of crayfish, as there are positive changes in both aroma and shelf life in the processing of crayfish. So, Chinisa et al. (2017) stated in their study that 95.6% smoking, 35.6% salting, and 20.0% sun drying process gives crayfish a pleasant taste and is consumed more. Similarly, Ba et al. (2021) showed in their study that the marketing of crayfish by processing can be more profitable. Sertkaya and Gurel (2023) experimented with different sauces on crayfish and reported that the sauce prolonged the shelf life of foods and had a positive effect on consumption and marketing. They also reported that the best results were obtained from the sauce with the addition of garlic. The increased development of these value-added products is expected to contribute to the spread of crayfish to a wider consumer base. Commercially available forms of crayfish are either live or boiled whole crayfish. Crayfish processing and peeling plants are based on the process of boiling or steaming crayfish until fully cooked, followed by hand peeling and packaging, and then distributing them chilled or frozen (Lovell, 1968; Romaire et al., 2005). Crayfish processing has become a major part of the crayfish industry. Crayfish processing is a modern industry that produces high-quality products for consumption worldwide (Moody, 1989; Davis et al., 1994). As mentioned earlier, crayfish are available live or boiled and ready to eat but are also available as harvested tail meat for the convenience of consumers and restaurateurs (Romaire et al., 2005).

Turkey exports an annual average of 440,364 kg of canned crayfish. With an average unit price of $10.12 per kg, Turkey earns $4,458,809. It exports an average of 51,268 kg of freshwater crayfish meal, paste and pellets annually, valued at $338,926 at an average unit price of $6.61 per kg. In addition, the average annual export volume for frozen or live crayfish is 42,327 kg valued at $163,509, with an average unit price of $3.86 per kg. In terms of countries, Turkey's main export destination for crayfish products is Sweden with an average annual export volume of 390,252 kg valued at $41,231,013 with an average unit price of $10.56 per kg (about 70%). Other important export countries are Russia (790,887 kg, $3,116,688, $3.94 per kg), Moldova (135,146 kg, $706,339, $5.23 per kg) and Belgium (111,509 kg, $791,811, $7.10 per kg). The United States also shows a high unit price of $12.35 per kg with an export volume of 65,783 kg valued at $812,253.

Sweden stands out in Turkey's exports in this respect. Due to the increasing demand for frozen and processed products due to the Covid-19 pandemic between 2019-2020, it is thought that the highest exports will be in these years (Can et al., 2020; Demirci et al., 2020). As a result, crayfish in our natural waters are an important source of protein and an export product, providing significant foreign currency inflow to Turkey. Higher economic benefits can be achieved by increasing product diversity.

Although the crayfish market in Europe and Scandinavian countries is well developed and has a variety of applications, there is little awareness of the product in the domestic market in Turkey. In the food industry, crayfish are widely used in soups, stews, pasta, and salads. In scientific research, it is valued and used in bio-ecology and behavioral studies. Also, in the aquarium trade, especially colorful species are preferred for aesthetic purposes. Due to their physiological similarities with humans, crayfish are used in biomedical research to study neural mechanisms, immune responses, and drug testing (Stein et al., 2022).

Considering the number of tourists coming to Turkey, especially Scandinavian nationals and others, the crayfish market has significant potential for the domestic market. Production in Turkey is entirely export-oriented, with restaurants and hotels taking over this role at the point of consumption. Recent studies show that per capita consumption of crayfish in Scandinavian countries is high, even leading the way (Yavuzyılmaz and Aydın, 2019). Therefore, with the high number of tourists visiting Turkey, it is inevitable to reconsider crayfish in terms of product diversity and to provide inputs to the national economy.

Although crawfish has long been a staple in the kitchens of regions such as Louisiana in the United States, it is now making its way onto dinner tables worldwide (Source). Increasing consumption of processed seafood due to changing consumer lifestyles and busy work schedules is also seen as one of the factors driving the growth of the crayfish market. Other factors such as increasing spending capacities of consumers, easy product availability on e-commerce platforms, and increasing demand for ornamental products are also anticipated to drive the market growth. Moreover, widespread adoption of the product as it helps in weight loss, muscle building, maintaining body fluids, treating inflammations, promoting healthy skin, repairing damaged cells, enhancing eyesight, increasing fertility, and preventing depression due to increasing health awareness among the masses is also seen as another factor driving the market growth (Bonilla et al., 2020). According to the crayfish market analysis, global interest in gastronomy has led to a resurgence in the popularity of crayfish. Crayfish sweet and tender meats have gained a coveted place in cuisines as diverse as China and Scandinavia. The rise of food tourism and culinary experiences has introduced more people to the exquisite taste of

crayfish, which is contributing to increased demand (Shackelford, 2014). Crayfish is appreciated for its adaptability to a variety of dishes. They can be grilled, boiled, steamed, sautéed, or used as a base for flavorful broths and stews, further driving demand in the crawfish market. An expanding global palate, coupled with growing appreciation for diverse culinary experiences, is driving demand for unique and exotic seafood (Yang et al., 2022; Shen et al., 2024).

5. CONCLUSION

Although Turkey has great potential to increase crayfish production, the harvest and export values are currently unsatisfactory. However, it is clear that increasing the crayfish harvest in parallel with exports will lead to a higher income increase for the Turkish economy, as it has done in the past. It is extremely important to increase promotional activities to increase domestic consumption. Especially in the summer months when crayfish fishing is carried out, tourism activities are the most intense in Turkey. Establishing connections with accommodation facilities, hotels, and restaurants in the tourism region and carrying out the necessary work to include crayfish in the food menu will contribute significantly to the appreciation of this product. In addition, further studies should be carried out to increase the variety of products and to determine which of the cooking techniques is more suitable for the taste of crayfish consumers. Crayfish are also in high demand during the holiday period (October to December) when people living in Europe are ready to spend some money on luxury products and during the summer holidays when tourists are willing to spend more time in Turkey. Accordingly, regional regulations should be made in terms of crayfish bans and practices.\

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7. STATEMENTS AND DECLARATIONS

7.1. Authors Contributions

All authors contributed to the study conception and design. Data collection was performed by Sevil Demirci and Emrah Şimşek. Data analysis was conducted by Aydın Demirci and Yavuz Mazlum. The first draft of the manuscript was written by Yavuz Mazlum. All authors read and approved the final manuscript.

7.2. Conflict of Interests

The authors declare that they have no known conflict of interests that could have appeared to influence the work reported in this paper.

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The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

7.4. Ethical Approval

The authors declare that formal consent is not required for this type of study.

7.5. Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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