# US FISHING VESSEL POWERING AND NOx EMISSIONS

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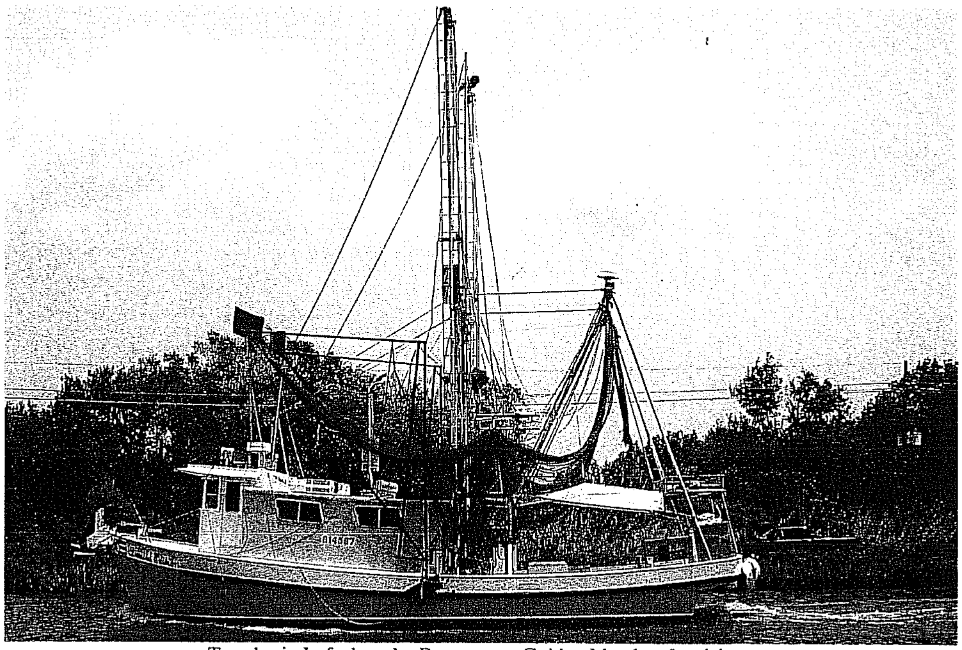

Trawler in Lafachouche Bayou near Golden Meadow Louisiana

ABSTRACT

This paper presents the results of SNAME Small Craft Panel SC-3 Fishing Systems investigation of trends in US fishing vessel (L≥22.9 m) powering and NOx emissions (1900-2000). The study estimates the 1,299 vessels in the US fishing fleet produce 306 tons/day of NOx. The largest powers are found in the decades of 1960-1980. The actual power Kw is compared to a reference power $Kw_o$ using the Powering Index Ration PIR= Kw/ $Kw_o$. It was found that 50-80% of the power in seiners, trawlers, crabber/trapper/clam vessels have PIR >2.5. The reduction of fishing vessel diesel engine NOx can be best achieved by adopting acceptable levels of vessel power/length for the basis of revenue and tax rather than using the vessel age as emissions reduction criteria.

KEY WORDS: NOx, Marine Engineering, Diesel Engine Emissions, Fishing Boat, Powering, Powering Index Ratio.

NOMENCLATURE

| | |
|---|---|
| B | Fishing Vessel Beam |
| Ei | Fishing vessel emissions kg/day |
| GRT | Fishing vessel Gross Registered Tons |
| Ki | Emissions per tone of fuel burned kg/ton fuel |
| Kw | Fishing Vessel propulsion power Kw |
| $Kw_o$ | Reference power based on length L |
| L | Fishing vessel length m |
| PIR | Fishing vessel Powering Index Ratio eq (3) |
| SFR | Engine specific fuel rate assumed as 220 g/Kw-hr |
| T | Operating time here taken as 24hrs/day |

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## Introduction and background

This paper presents the results from SNAME Small Craft Panel SC-3 Fishing Systems. The theme of the panel work was an assessment of US fishing vessel powering trends (1900-2000) and the corresponding engine emissions. With the adoption of the IMO and EPA regulations on new marine engine emissions, it is useful to examine the existing US fishing fleet with the goals of:

1. Estimate the engine emissions from larger US Fishing vessels
2. Identify operating fishing vessels that are high polluters

The ground work for this study is found in the marine engineering literature. Lloyd's Register of Shipping completed a series of on- board measurements of marine diesel emissions. (Annon, 1995) Their diesel engine emission measurements are summarized in Table 1. The values are representative for both steady state and transient operations.

These values are used here to estimate US fishing vessel engine

| Emission | Ki =Kg/ton fuel | g/Kw hr |
|---|---|---|
| NOx | 87* 57** | 17* 12** |
| CO | 7.4 | 1.6 |
| HC | 2.4 | 0.5 |
| $CO_2$ | 3170 | 660 |

Table 1 Measured Marine Diesel Engine Emissions (Annon, 1995)
Key: *slow speed diesel, **medium speed diesel

Emissions. Using the value of Ki in Table 1, the fishing vessel emissions Ei kg/day are easily estimated on the basis of ton of fuel burned times the factor Ki for each exhaust gas.

$$Ei = KixSFRxKwxT \quad \text{Kg/day} \qquad (1)$$

The choice of Ei units of kg/day reflects current of US fishing vessel operations where a fishing boat may operate seasonally only 180 to 270 days/year.

In an earlier study (Latorre, 2001) it was noted that a large number of the US fishing fleet are powered with large output engines. This is hard to quantify without an appropriate standard. Fortunately, Fyson (1985) published a design graph of fishing vessel engine power versus length for 10m<L<70m. The trend line for $Kw_o$ is given by the following equation:

$$Kw_o = 3.9217\,L + 0.2054\,L^2 \quad \text{for } 10<L<70 \text{ m} \qquad (2)$$

Equation 2 makes it possible to introduce the Powering Index Ratio PIR. This is the ratio of actual fishing vessel power Kw to reference power $Kw_o$ for the boat length L.

$$PIR = Kw/ Kw_o \qquad (3)$$

PIR values of 1.5 to 2.5 are reasonable for vessels that tow their fishing gear. i.e. trawler, seiner, etc. Nevertheless, the analysis of US fishing fleet powering reveals vessels with PIR values as high as 4 to 6.

Fishing vessels with high PIR values will be expensive to operate as well as create excessive propulsion plant emissions compared to a similar vessel with a small engine output.

| Fishing Vessel Type | No | PERCENT |
|---|---|---|
| N/A (incomplete for detailed analysis) | 484 | 37% |
| MULTIPLE TYPE VESSELS | 261 | 20% |
| SEINERS | 130 | 10% |
| TRAWLERS | 117 | 9% |
| TENDER | 86 | 7% |
| CRABBER / TRAPPER / CLAMMER | 68 | 5% |
| FACTORY | 47 | 4% |
| PROCESSOR | 37 | 3% |
| LONGLINER | 26 | 2% |
| UN-POWERED | 18 | 1% |
| MISC | 16 | 1% |
| SCALLOPER | 14 | 1% |
| SHRIMPER | 12 | 1% |
| FREIGHTER | 1 | 0% |
| **TOTAL** | **1317** | **100%** |

Table 2 Fishboat-2000 database entries by Fishing Vessel type

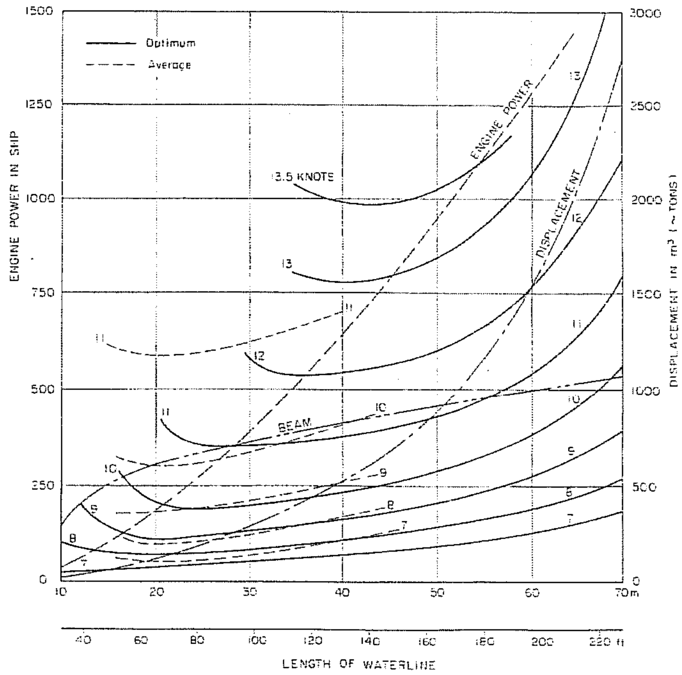


Fig. 1 Fishing Vessel engine power Kw versus Length L Fyson (1985)

**FISHBOAT-2000 Database: US fishing vessel powering trends**

The Fishboat-2000 database contains the following entries:

Fish Boat i = (Name, Type, State, Year Built, L, B, GRT, Kw)

The Fishboat 2000 database includes data from several sources including ABS, DNV as well as Thompsen (1997). The Fishboat 2000 database contains 1,317 fishing vessels with L >22.9 m. They are summarized by type in Table 2. With shorter fishing seasons, a number of fishing vessels are equipped for fishing different types of catch. They are denoted as multiple type vessels in Table 2. The powered fishing vessel sub-group has a population of 1,299 fishing vessels. The distribution by type is shown in Fig 2a. Fig. 2b is a breakdown of the multiple types fishing vessel according to the vessel type

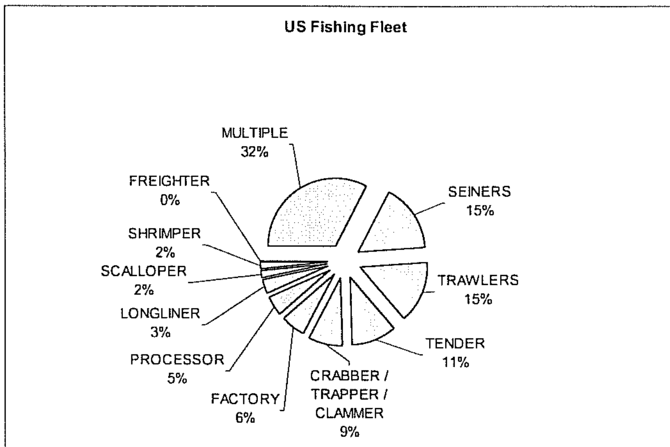


Fig 2a Breakdown of US Fishboat Database

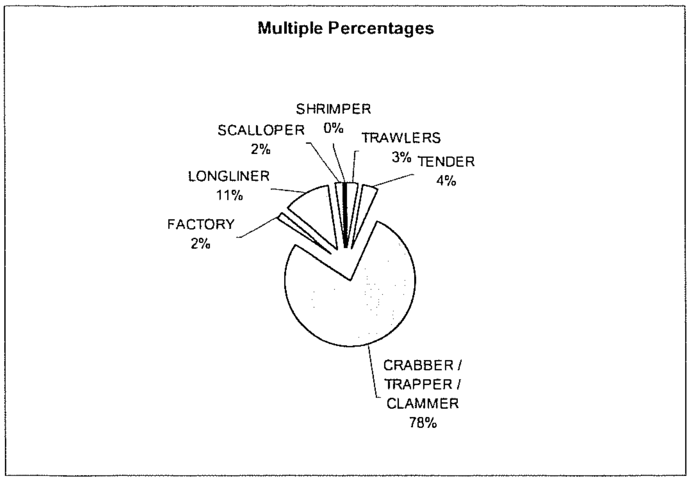


Fig. 2-b Multiple type fishing vessels by fishing vessel types

**US Fishing Vessel Powering Trends**

A second analysis was completed to examine installed fishing vessel propulsion power Kw/decade. The results shown in Fig. 3 indicate a significant increase in fishing vessel installed power in 1970 and 1980. These trends are also evident in Fig. 4 where the average power Kw is plotted by decade. It is clear from this plot that from 1960 to 1980 there is a significant increase in the average propulsive power Kw/fishing vessel.

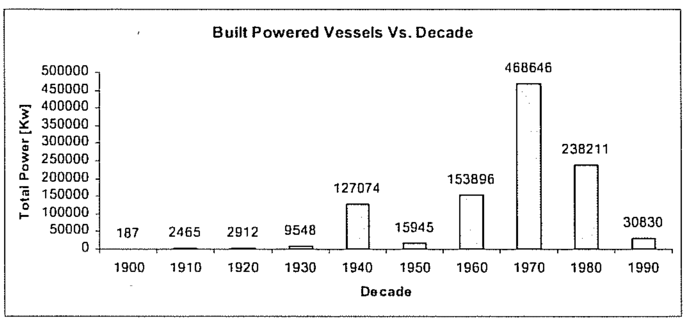


Fig. 3 US Fishing Vessel Total installed propulsion power by decade

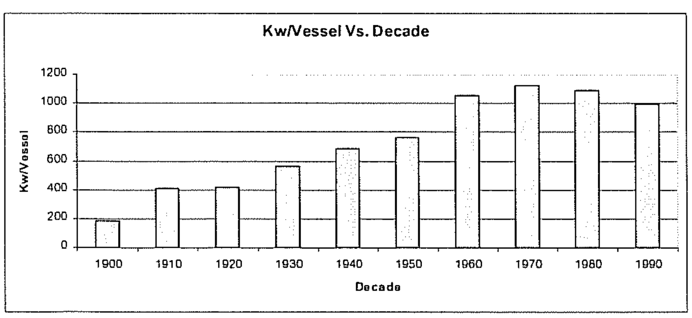


Fig 4 US Fishing Vessel average installed power Kw/vessel per decade

| Emissions | Value | Units |
|---|---|---|
| NOx | 306 | [ton/day] |
| CO | 40 | [ton/day] |
| HC | 13 | [ton/day] |
| $CO_2$ | 16995 | [ton/day] |

Table 3 Estimate of US Fishing vessel engine Emissions ton/day

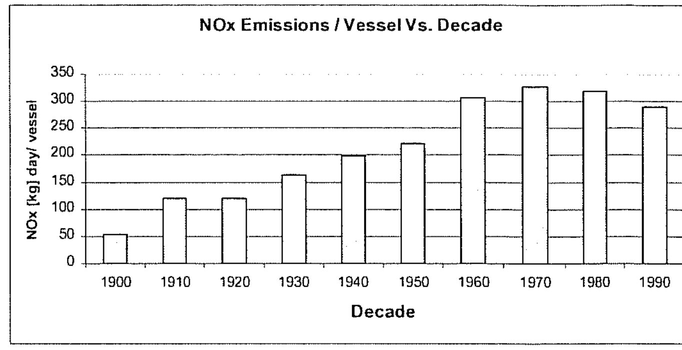


Fig. 5 US Fishing Vessel NOx by decade

This indicates the more recent fishing vessels have a larger propulsion engine set. So only in the past decade did the engine output decrease. Factors contributing to this decrease are a tighter economic situation and higher fuel cost

**US Fishing Vessel propulsion plant emissions**

The US fishing vessel engine emissions Kg/day are estimated using the vessel power data from FISHBOAT-2000. Table 3 summarizes the US fishing vessel engine emissions/day obtained from eq (1). These emission estimates are useful in quantifying the environmental impact from operating larger US fishing vessels. As noted earlier, a large number of the US vessels are used in seasonal fishing resulting in an operational year of 180 to 270 days. Consequently, it is difficult to quote a value of emissions/year. A more detailed estimate would include auxiliary engine exhaust gas emissions i.e. from diesel powered electric generators etc. This was not possible in this work due to lack of data.

The trend of larger average engine output shown in Fig 4 is reflected in the NOx values shown in Fig. 5. Figure 5 show that relatively newer US fishing vessels built in 1960 -1980 have significantly higher NOx (300 kg/day) averages compared to (100-200 kg/day) average .values for vessels built in 1920-1950.

**US Fishing Vessel Powering Trends by Vessel Type**

In order to further clarify US fishing vessel powering trends, A detailed powering analysis was completed for the following fishing vessel types from Table 2:

- Seiner
- Trawler
- Tender
- Crabber/trapper/clammer

The powering Kw data for each fishing vessel is plotted as a function of vessel length L for the Seiner (Fig. 6), Trawler (Fig. 7) Tender (Fig. 8) and Cabber/trapper/clam Vessels (Fig. 9). For reference, the $Kw_o$ curve from eq (1) is plotted. The results show for vessels with larger length the actual propulsion power Kw is significantly larger than the reference value $Kw_o$.

The corresponding plots of Powering Index Ratio PIR from equation (3) Are plotted in Figs. 10-13. These plots show two groupings:

Group I $1.0 < PIR < 2.5$

Group II $2.5 < PIR$

Table 4 summarizes the breakdown by vessel types into Groups I and II. Table 4 shows the breakdown in terms of the number of vessels as well as the total Kw power values. A general trend appears that the vessels in Group II represent 50-80% of the total power Kw for the seiner, trawler, and crabber/trapper/clam vessel types. This further shows the significant growth in fishing vessel power observed earlier.

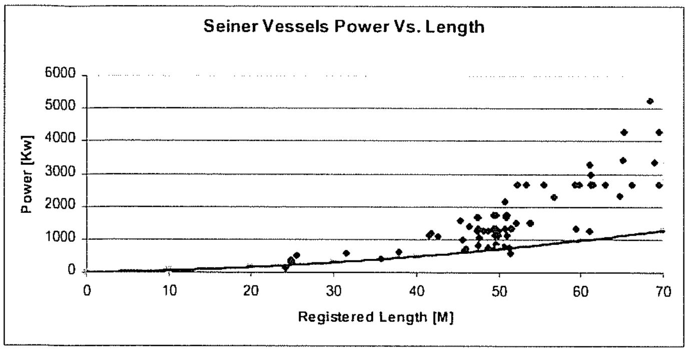


Fig. 6 Comparison of US Seiner power Kw with curve of $Kw_o$.

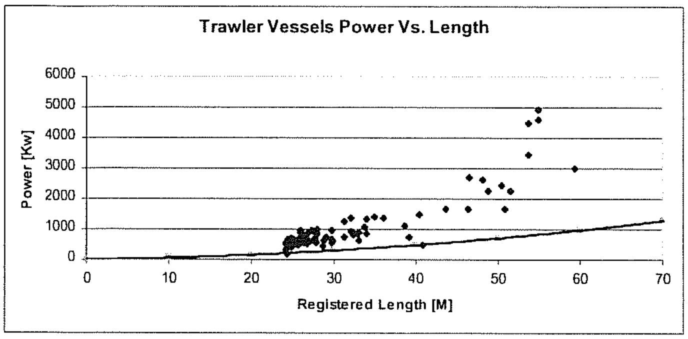


Fig 7 Comparison of US Trawler power Kw with curve of $Kw_o$.

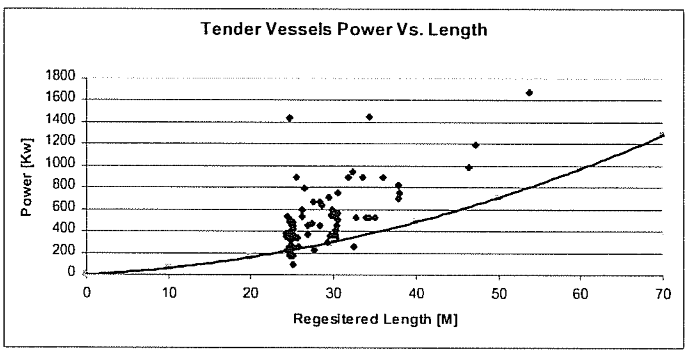


Fig. 8 Comparison of US Tender power Kw with curve of $Kw_o$.

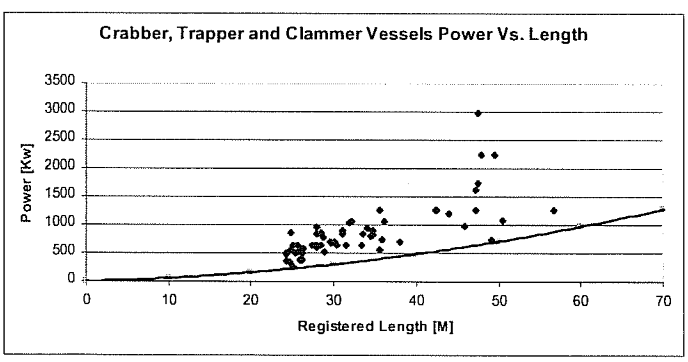


Fig. 9 Comparison of US Crabber/Trapper/Clamming Vessel power Kw with curve of $Kw_o$.

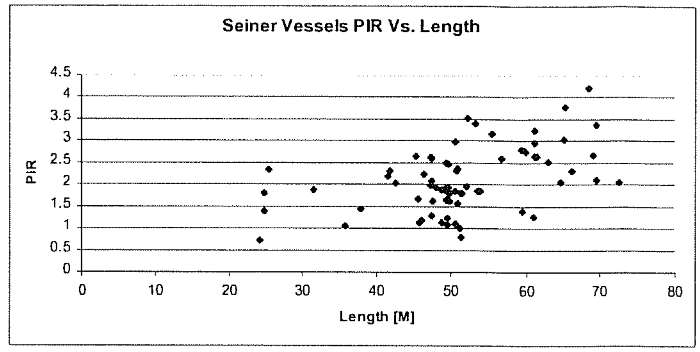


Fig. 10 Comparison of Powering Index Ratio PIR for US Seiners

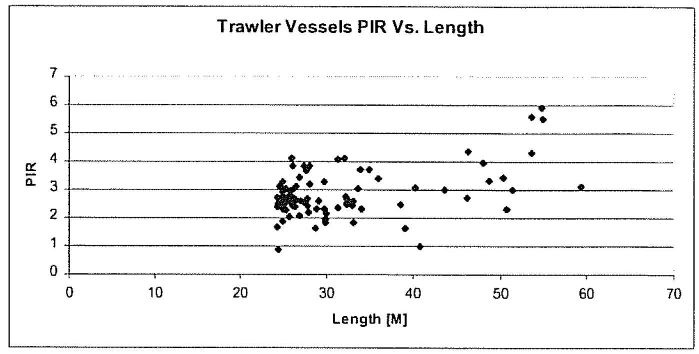


Fig. 11 Comparison of Powering Index Ratio PIR for US Trawlers

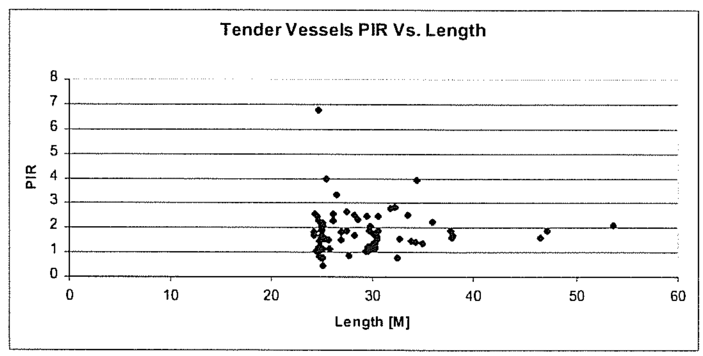


Fig. 12 Comparison of Powering Index Ratio PIR for US Tenders

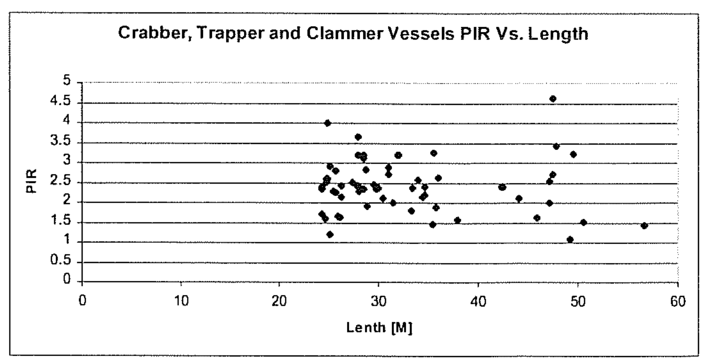


Fig. 13 Comparison of Powering Index Ratio PIR for US Crabber Trapper and Clam Vessels

| Vessel Type | No* | Total Kw | Group I 1.0 ≤PIR≤ 2.5 | | Group II 2.5< PIR | |
|---|---|---|---|---|---|---|
| | | | No (%) | Kw (%) | No (%) | Kw (%) |
| Seiner | 120 | 209,714 | 82 (68%) | 104,858 (50%) | 38 (32%) | 104,856 (50%) |
| Trawler | 98 | 98,716 | 33 (34%) | 20,456 (20%) | 65 (66%) | 78,260 (80%) |
| Tender | 81 | 40,840 | 70 (86%) | 31,039 (76%) | 11 (14%) | 9,801 (24%) |
| Crabber /Trapper/ Clam | 66 | 56,499 | 40 (60%) | 28,167 (50%) | 26 (40%) | 28,332 (50%) |

Table 4 US Fishing Vessel Powering Trends by Vessel Type

Key: * Smaller No from Table 2 due to lack of powering data.

**Discussion and Conclusions**

This paper has presented an analysis of large (L> 22.9 m) US fishing vessel powering and NOx emissions. The analysis includes an estimate of the US fishing fleet emissions, the powering trends in the US fishing fleet arranged by decade and the corresponding emissions by decade. This results show there was a significant increase in the number of fishing vessels in the 1970-1980 decades. In addition these vessels have a large value of Kw/vessel indicating an increase in the installed propulsion power.

By introducing a base line power $Kw_0$ it is possible to quantitatively examine this trend in powering using the powering index ratio PIR = Kw/ $Kw_0$ . The PIR analysis shows the fishing vessels can be assigned to:

- Group I (1.0 ≤PIR≤ 2.5)
- Group II (2.5< PIR).

The results in Table 4 show the vessels in Group II represent 50-80% of the total power Kw for the seiner, trawler and crabber/trapper/clam vessel types. This leads to the following conclusions:

1. The current US fishing fleet experienced a growth in numbers and average installed power in the 1970-1980's.
2. An estimate of 306 ton/day NOx was obtained in the fleet emission analysis.
3. The analysis of vessel types shows that the installed power can be characterized by a baseline power denoted by $Kw_0$.
4. Introducing the Powering index ratio PIV = $Kw/Kw_0$, it was shown the PIV > 2.5 for 32% of the Seiners, 66% of the trawlers and 40% of the crabber/trapper/claim vessels.

Finally, It is recommended that to effectively reduce NOx emissions, attention be given to the vessel installed power rather than the vessel size, age or GRT in drafting legislation and regulations.


## ACKNOWLEDGEMENTS

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