航水研ノート，空と海，第8号，1986

APPLICATIONS OF SATELLITE REMOTE SENSING TO FISHERIES

R. Michael LAURS*

The use of satellite remote sensing to provide synoptic measurements of the ocean is becoming increasingly important in fisheries applications. Variations in ocean conditions play key roles in natural fluctuations of fish stocks and in their vulnerability to harvesting. Information on the changing ocean, rather than on average ocean conditions, is necessary to understand and eventually to predict the effects of the marine environment on fish populations. The evolving capabilities of satellite sensor and data-processing technology, combined with conventional data collection techniques, provide a powerful tool toward ensuring the wise use of living marine resources.

Laurs and Brucks (1985) review fisheries applications of satellite oceanic remote sensing in the United States. Examples of recent and potential uses of satellite imagery in U. S. fisheries in the eastern North Pacific are given in Fiedler et al. (1985). Yamanaka (1982) describes the utilization of satellite imagery in Japanese fisheries. Gower (1982) gives an overview of the different kinds of remote sensing data relevant to fisheries science and oceanography, and Montgomery (1981) discusses the utility of satellite imagery to ocean industries, including fisheries.

Satellite Data Sources and Limitations

Satellite remote sensing applications in U. S. fisheries have concentrated on the measurements of ocean temperature and color, and computation of ocean transport based on satellite measured wind stress.

Ocean temperature

Virtually all fisheries studies employing satellite ocean temperature measurements have utilized imagery from thermal infrared sensors. The advanced infrared sensors, notably the Advanced Very High Resolution Radiometer (AVHRR) aboard the TIROS orbiting meteorological satellites, are characterized by high sensitivity in narrow wave lengths, fine ground resolution, and an extensive data archive (Fiedler et al., 1985). These sensors yield high quality data which except for some limitations, meet the requirements for most fishery investigations (Laurs, 1985).

* NOAA, National Marine Fisheries Service, Southwest Fish. Cent., 8604, LA Jolla, Shore Dr., La Jolla, CA 92038, U. S. A.

There have been a very limited number of attempts to apply ocean temperature measurements made from microwave instruments aboard satellites to fisheries studies. These attempts have been only marginally successful, mostly because of the large footprint of the measurements and the contamination of the data in the vicinity of land. However, an adequate evaluation of the utility of satellite microwave ocean temperature measurements in fisheries problems has yet to be conducted. Efforts to do so have been hampered because of difficulties in obtaining microwave temperature data and lack of high speed data processing capabilities to process it (Niebaur, pers. comm.)

Ocean color

The Coastal Zone Color Scanner (CZCS) on board the Nimbus-7 satellite, launched in October 1978, is the first sensor in orbit that is specifically designed to measure ocean color (Hovis et al., 1980). The CZCS is capable of measuring very subtle variations in water color resulting primarily from variations in phytoplankton concentrations. Ocean color measurements from the CZCS are being used in fishery resource applications to determine the locations of oceanic fronts, effluents, and water masses; to determine circulation patterns; and to make quantitative measurements of chlorophyll and sestonic concentrations.

Ocean winds

The scatterometer (SASS) aboard the Seasat-A satellite provided data which demonstrate the importance to fisheries of high resolution surface wind stress measurements made from space. Wind stress measurements made by satellite can be used to calculate ocean surface layer transport, which controls the distribution of larval stages and the subsequent recruitment and harvests of many marine fishes and shrimps (Brucks et al., in press). Satellite measurements of winds are also important in the detection of wind conditions that affect the safety and performance of fishing vessels at sea. Although the data record of satellite measured winds is very limited as a result of the unfortunate premature failure of the Seasat satellite, extensive global coverage of oceanic surface winds will be made by satellite systems planned for launch in the late 1980s.

Data limitations

The major inadequacy of present satellite sensors that make measurements in the visible and infrared bands is that they can measure sea surface temperature and ocean color only through a cloud-free atmosphere. This has hampered the utilization and acceptance of satellite technology in fisheries research and fish harvesting applications because many important fisheries are located in areas which have dense cloud cover much of the time.

Fiedler et al. (1985) examined the seasonal and areal distribution of cloud conditions over the eastern North Pacific and discussed the probabilities of conditions suitable for satellite coverage. They found that off the coast of Baja and California from latitude 30° to 38°N the most favorable conditions for remote sensing are from October through April, whereas a dense layer of low stratus clouds covers the coastal waters during the summer upwelling season. Off the coast of northern California, Oregon, and Washington from latitude 40° to 50°N the best conditions for remote sensing occur from August to October. North of latitude 50°N mean cloud over increases and is consistently 70% or greater in the Gulf of Alaska although March and April may be relatively clear.

Another draw back to satellite infrared temperature and ocean color measurements is their restriction to the upper most layer of the ocean surface. Although AVHRR measurements are often representative of general temperature conditions in the upper mixed layer (Bernstein, 1977), many important species live below the thermocline or on the bottom, where temperature patterns are not necessarily apparent at the surface. Another shortcoming of infrared imagery is that its use to detect fronts in open ocean areas may be limited to periods prior to the onset of seasonal warming. The use of ocean color imagery from the CZCS can often circumvent this problem (Laurs et al. 1984).

In spite of the limitations noted, data from the CZCS and advanced infrared sensors on satellites meet the general needs for many fisheries applications. The development of reliable microwave radiometers that can measure sea surface temperature with high resolution through clouds, along with advanced infrared sensors, however, is required to make full utilization in fisheries of ocean temperatures measured from space.

While the requirements of satellite sensor measurements for fisheries applications have been treated extensively (e. g., Sherman, 1980) specification of requirements for ground processing and data delivery systems have been neglected and require further development. There are pressing needs to increase the availability of ocean measurements made by satellite for use in fisheries applications. In some cases, direct reception and processing of the satellite data are required. In others the routine distribution of earth-located and geographically rectified charts of level 3 data will suffice.

Use of Satellite Measurements in Fisheries Research

Variations in environmental conditions affect the recruitment, distribution, abundance, and availability of fishery resources. It is not possible to measure remotely from satellites the entire spectrum of information needed to assess changes in the marine environment. However, knowledge of important oceanographic conditions and processes affecting fish populations may often be deduced using ocean measurements made by satellite. e. g., distribution of surface isotherms, locations of oceanic frontal boundaries, information on currents and circulation patterns, regions of upwelling, and so on.

Measurement of marine fish habitat

Ocean measurements made by satellite remote sensing can be extremely useful in defining the distribution of marine fish habitats. Lasker et al. (1981) and Fiedler (1983) have demonstrated that the northern boundary of northern anchovy spawning habitat in the Southern California Bight may be delimited using AVHRR imagery from NOAA polar orbiting satellites. In general, the northern extent of spawning in the Bight and the offshore extent of spawning north of Santa Catalina Island are limited by cold, upwelled waters advected south of Point Conception. The cold waters are readily evident in satellite infrared imagery of the region (Fig. 2). The southern limit of spawning may be defined using ocean color measurements made by the CZCS aboard the Nimbus-7 satellite showing low chlorophyll concentrations (Fiedler, 1983).

The distribution and availability of albacore tuna off the west coast of the United States have been found to be related to oceanic fronts seen in AVHRR infrared and CZCS imagery (Laurs et al. 1984). Commercially fishable aggregations of albacore are found in warm, blue oceanic waters near temperature and color fronts on the seaward edge of coastal water masses (Figs. 4 and 5). These oceanic boundary features, which are believed to result primarily from coastal upwelling, are clearly observable in satellite imagery collected along the U. S. Pacific coast. The distribution of albacore during winter time in regions hundreds of miles off the coast has also been related to sea surface temperature fronts, believed to mark the outer boundary of the California Current observed in AVHRR imagery (Laurs et al. 1981).

The small-scale migration patterns of albacore in relation to oceanic frontal boundaries was investigated using ocean color and infrared data collected contemporaneously with observations made from ships at sea by Laurs and Austin (in press). Nimbus-7 CZCS and NOAA-6 satellite AVHRR infrared data were collected in conjunction with field experiments where acoustic telemetering was used to track the horizontal and vertical movements of free-swimming albacore, and expendable bathythermograph (XBT) observations were made to determine subsurface ocean thermal structure. Three albacore were tracked for approximately 24 hr and one for about 15 hr. The results showed that (1) total distances tracked ranged rom about 40 to 60 km, with all fish remaining in the same parcel of warm water that was separated from waters to the north, south, and inshore by about a 2°C temperature gradient as shown by infrared thermal imagery ; (2) tracked fish spent most of the time in waters within and below the thermocline, and only small amounts of time in the upper mixed layer (Fig. 6) ; (3) the fish exhibited marked vertical excursions in depth with the range being larger during the day than at night ; (4) the fish spent most time in waters with temperatures considerably lower than what has been generally believed to be the preferred temperature range for albacore ; and (5) when changing depth, the fish frequently within a 20-min period, passed through a vertical gradient of temperature amounting to 6-7°C or about 3 + times greater than the horizontal temperature gradient at the surface indicated by ship measurements and the infrared thermal imagery. These findings indicate that the reasons tuna aggregate on the warm side of surface temperature fronts-an economically significant phenomenon that has been observed on scientific cruises and is well known by fishermen - may not be related to thermal-physiological mechanisms (Neill, 1976). Instead, water clarity as it affects the ability of time to detect prey may be in an underlying mechanism.

Satellite infrared measurements have also been used to trace the development and duration of the various bluefin tuna fisheries along the east coast of the United States (Roffer et al. 1982). These fisheries follow the movement of seasonal warming of near-surface waters which are monitored by observing the northerly progression of the 19-20°C isotherms in satellite infrared imagery. Limited success has been achieved during winter months in relating the distribution of tuna longline fishing in the Gulf of Mexico with position of the Loop Current deduced from temperature frontal patterns observed in Geostationary Orbiting Earth Satellite (GOES) infrared imagery (Leming, Internal Report, NMFS and Maul et al., 1984). In summer months after seasonal warming has occurred, it is not possible to resolve temperature frontal structure in the GOES infrared imagery of the Gulf of Mexico.

Satellite remote sensing has been an especially important tool during the recent El Niño for monitoring anomalous ocean conditions along the U. S. Pacific coast (Fiedler, 1984a). The satellite imagery contains invaluable information for use in assessing the effects of the El Niño conditions on U. S. west coast fisheries. Virtually all of the fisheries were affected in varying degrees, with some fisheries showing benefits from the El Niño and others being harmed substantially. Many fish populations experienced changes in their distribution and centers of abundances. For example, there were shifts in the usual distribution of anchovy spawning which Fiedler (1984b) found could be delineated using AVHRR infrared imagery.

Use of satellite in design of field studies and interporetation of ship data

Another area where satellite data are being used in fisheries research is to assist in the design of field studies and to guide research operations on fishery research vessels. This has been an extremely important use of satellite data at the National Marine Fisheries Service Southwest Fisheries Center. Satellite data are used in planning sampling patterns and cruise tracks, to make adjustments in cruise operations while at sea, and to assist in the intrepretation of cruise results. The use of satellite measurements has markedly enhanced sampling ability, enabling researchers to sample the right places at the right times and has resulted in considerable savings in time and funds. This important application of satellite remote sensing usually requires direct reception and processing of satellite data in near real time. The cost savings for conducting research can be significant, since a single satellite image from data received and processed in a matter of a few hours can save days of expensive ship time by locating significant ocean feature and permitting optimum sampling effort (Fiedler et al., 1985). It can be used to validate the interpolation and extrapolation of shipboard measurement and as the basis for interpretation of measurable patterns and possible mechanism responsible for spatial and temporal variability observed in shipboard observations (LASKER et al. 1981).

Potential use of satellite data in fisheries studies

There are a number of fishery research situations where satellite data can potentially play an important part in the future. For example, satellite measurements can provide vast amounts of oceanographic data for use in evaluating the status of fish stocks as advanced models for fishery stock assessment are developed which incorporate environmental information. Investigations concerned with determining interactions between fisheries and pollution are prime candidates for the use of satellite ocean measurements. For example, ocean color and other imagery can be used to determine dispersion patterns of waste dumped at sea. Satellite measurements of ocean chlorophyll also may be extremely useful in studies to model ecosystem energy budget to estimate potential fish stock production.

Use of Satellite Measurements in Fisheries-Aid Products for Fishermen

Several projects and programs have used or are using satellite-derived ocean data in fisheries-aid products which are distributed to U. S. fishermen by a variety of mechanisms, including radio facsimile transmission, voice broadcast, U. S. mail, and telephone telecopier. A prime motivation leading to the expanded use of satellite observations in fisheries-aid products was provided by the Seasat Commercial Demonstration Program sponsored by the National Aeronautics and Space Administration/Jet Propulsion Laboratory in Pasadena, California. This program led to the development of an operational Satellite Data Distribution System used to distribute oceanographic products to ocean users (Montgomery, 1981).

Charts showing the locations of oceanic thermal boundaries are derived from AVHRR infrared imagery from polar orbiting satellites and are provided to commercial and recreational fishermen for use in locating potentially productive fishing grounds along the Pacific coast from central Baja California to British Columbia, Canada (Breaker, 1981). Fishermen use these charts to save time in searching for productive fishing areas associated with oceanic frontal features. High resolution infrared images from the GOES satellite and ship reports are used in the preparation of charts for waters off the Atlantic Coast, which are distributed to fishermen and other marine users (Chamberlain, 1981). Of particular interest to fishermen, these charts show the outer limit of the shelf water mass, in which many fishery resource species reside. The charts also give information on the numbers, sizes, and persistence of warmcore Gulf Stream rings, which can markedly alter conditions on the fishing grounds. These charts have been particularly useful to lobster fishermen in reducing loss of fishing pots as a result of strong currents of the Gulf Stream warmcore eddies. Charts based on GOES infrared imagery are also prepared to show the path of the Loop Current in the Gulf of Mexico and are used mostly by recreational fishermen (Lowry and Leaky, 1982).

Experimental ocean color boundary charts based on CZCS imagery are distributed to U. S. westcoast fishermen (Montgomery, 1981). These charts delienate strong gradients in the blue/green color ratio (Channel 1/channel 3 radiances). They are produced at almost weekly intervals depending on cloud conditions. and cover coastal areas up to 700,000 km² between Guadalupe Island and Vancouver Island. Nimbus-7 CZCS passes along the Pacific coast are collected at the Scripps Institution of Oceanography (SIO) Satellite Oceanography and transmitted by radiofacsimile the following day to fishing boats at sea from radio station WWD in La Jolla, California. Color photographs of the satellite images are also distributed by express mail to various fishing ports and to Sea Grant marine advisors in daily contact with fishermen. The color boundary charts and photographs are used primarily by commercial albacore swordfish and salmon fishermen, and recreational fishermen in southern California. Fishermen use the color boundary charts to locate color gradients or "breaks" which are important in determining potentially productive fishing areas.

REFERENCES

BRUCKS, J.T., T.D. LEMING, AND S.B. BUCKETT, JR. In press. A model investigation using high resolution SASS wind stress measurements to derive wind surface layer transport properties in the Gulf of Mexico. NOAA Tech. Rept.

FIEDLER, P.C. 1983. Satellite remote sensing of the habitat of spawning anchovy in the southern California Bight. CalCOFI Rept. 24 : 02-209

———. 1984a. Satellite observations of El Niño along the U. S. Pacific Coast. Science 224 : 1251-1254

———. 1984b. Some effects of El Niño 1983 on the northern anchovy. CalCOFI Rept. 25 : 53-38.

FIEDLER, P.C., G.B. SMITH, AND R.M. LAURS. 1985. Fisheries aplications of satellite data in the eastern North Pacific. Mar. Fish. Rev. 46 : 1-13

GOWER, J.F.R. 1982. General overview of the nature and use of satellite remote sensing data for fisheries application. NAFO Sci. Counc. Studies 4 : 7-19

HOVIS, W.A., D.K. CLARK, F. ANDERSON, R.W. AUSTIN, W.H. WILSON, E.T. BAKER, D. BALL, H. GORDON, J.L. MUELLER, S.Y. EL SAYED, B. STRUM, R.C. WRIGLEY, AND C.S. YENTSCH. 1980. Nimbus-7 coastal zone color scanner : System description and initial imagery. Science 210, 60-63.

LASKER, R., J. PELAEZ, AND R.M. LAURS. 1981. The use of satellite infrared imagery for describing ocean processes in relation to spawning of the northern anchovy *(Engraulis mordax)*. Remote Sensing Environ. 11 : 439-453.

LAURS, R.M., AND J.T. BRUCKS. 1985. Living Marine Resource Applications. In Barry Saltzman, ed., Advances in Geophysics 27 : 419-450

LAURS, R.M., R.J. LYNN, R. NISHIMOTO, AND R. DOTSON. 1981.

Albacore trolling and longling exploration in eastern North Pacific waters during mid-winter 1981. NOAA-TM-NMFS-SWFC-10.

LAURS, R.M., P.C. FIEDLER, AND D.R. MONTGOMERY. 1984.
Albacore tuna catch distributions relative to environmental features observed from satellites. Deep Sea Res. 31 : 1085-1099.

LEMING, T.D. 1981.
Ocean pelagics remote sensing applications. Interim Rept. NMFS (Internal Document).

MAUL, G.A., M. ROFFER, AND F.M. SOUSA. 1984.
Remotely sensed oceanographic patterns and variability of bluefin tuna catch in the Gulf of Mexico, Oceanol. Acta. 7, 469-479.

MONTGOMERY, D.R. 1981.
Commercial applications of satellite oceanography. Oceanus 24 : 56-65.

ROFFER, M., M. CARL, AND F. WILLIAMS. 1982.
Atlantic bluefin tuna oceanography remote sensing. Proc. 32nd Annual Tuna Conference, IATTC, La Jolla, California.

SHERMAN, J.W. III (ED)
NOAA Workshop on Oceanic Remote Sensing vol. 2, Workshop Support Document, National Oceanic and Atmospheric Administration, Washington, DC.

YAMANAKA, I. 1982.
Application of satellite remote sensing to fishery studies in Japan. NAFO Sci. Counc. Studies 4 : 41-50.

衛星リモートセンシングの米国漁業への応用

*R. Michael LAURS

摘　要

衛星データ・ソースとその限界

米国漁業への衛星の応用は水温，水色，および衛星によって測定された風のストレスから輸送を計算することに力が注がれている。

水温：AVHRR は，波長帯の幅が狭く高感度で地上分解能がすぐれ，データの蓄積も多く，幾つかの問題点はあるが，漁業調査の要望の大部分に応えている。

マイクロウェーブによる水温測定の企てはまだ多くない。それは地上分解能が悪く，陸に近いところではコンタミネーションがあり，またデータの高速処理能力に問題があるためである。しかし漁業のために衛星のマイクロ波による水温情報を応用する研究は今後も行わなければならない。

水色：NIMBUS-7 の CZCS は主に植物プランクトンによる水色の微細な相違を測定できる。これは前線，流出，水塊などの位置の探査，環流のパターン，クロロフィル量の測定など水産資源に対して応用されつつある。

海風：Seasat-A に搭載された散乱計 (SASS) により海上の風の正確な測定が漁業に大切であることが示された。これは稚魚の輸送や加入，漁獲などに影響する表層の輸送を求めるのに応用することができる。また衛星からの風の測定は言うまでもなく漁船の安全にも重要である。Seasat は寿命が短く，そのためデータの蓄積は少ないが 1980 年代後半には衛星による地球的規模での風のデータを集めるシステムが出来よう。

データの限界：現在のセンサーの第一の限界性は雲のないところでないと用いられないことである。これについては季節による雲量分布が調査された。

いま一つの障害は衛星資料が表面に限られることである。AVHRR は上部混合層迄の状態を示すことがしばしばあるが，生物のあるものはこれよりも深いところに住んでいる。

また外洋では，赤外画像で前線を見ることができるのは，夏季の水温上昇の始まる前に限られることである。これは CZCS による水色で補うことができる。

このようにいろいろの限界はあるが，AVHRR と CZCS の併用により漁業の問題の多くに対応することができるが，更に雲を透して水温を高精度で測定するマイクロ波センサーの進歩が望まれる。

センサーによる測定の漁業に対する要望に比べ，地上での資料処理，およびその伝達法に関する要望には立ち遅れがある。船上での直接受信・処理の要望もあるが，地上で作成し，地理補正をした図面の配布で十分なこともある。

漁業研究における衛星測定の応用

魚の生態に関係する海洋環境のすべてを衛星によって観測することは出来ないが，等温線，前線のような重要な海況は衛星資料から判断することができる。

* 米国商業漁業局南西漁業センター

海中の魚の行動の測定例

カタクチイワシ：南カリフォルニア湾での産卵の北限は Point Conception の南にある湧昇冷水で規定されるが，これは AVHRR 画像で明瞭に示される。また，その南限は CZCS による水色測定で，クロロフィルの少ない海域として識別できる。

ビンナガ：米国西海岸沖の漁場は沿岸水塊の沖側の水温および水色の境界に近い高温で青い外洋水にできる。この前線は沿岸湧昇によるものであり，衛星の AVHRR, CZCS 画像等によって明らかにみることができる。冬季にはビンナガの分布はやはり AVHRR でみられる遙か沖のカリフォルニア海流の外側の温度前線と関係をもっている。

CZCS および AVHR のデータにあわせて XBT による中層水温測定や音響テレメトリーを船上で行うことによりビンナガの小規模の回遊の有様が調査された。3 尾のビンナガを 24 時間，1 尾を 15 時間追跡したが，どれも赤外画像で判断される約 2℃の水温傾度によって判別される同一暖水塊にとどまること，魚は大部分の時間は温度躍層の内部またはその下部にいること，上下移動は夜間よりも日中で激しいこと，従来考えられていたよりもかなり低温な水域で過ごすこと，この場合，衛星や船舶資料によりみられる水温水平傾度の 3 倍以上もある 6～7℃の水温差を 20 分以内で乗り越えることなどがしられた。

クロマグロ：大西洋岸の春のクロマグロの北上は，赤外画像で示される 19～20℃の等温線の移動に従っている。冬のメキシコ湾では静止衛星 GOES による水温前線から判断された環状流（Loop Current）に関係した位置で，はえなわがある程度成功しているが，夏にはこの衛星の赤外画像では温度前線は判別できない。

エルニーニョ：殆ど総ての魚種がエルニーニョによって好影響，または悪影響をうけた。たとえば，カタクチイワシの産卵場の著しい移動があったがこれは AVHRR の画像により，水温変動が明らかに認められた。

海上調査の設計および船舶データの解釈に対する衛星の応用：

これは南西漁業センターにおける衛星の極めて重要な応用の 1 である。即ち，調査航路，観測点の位置，時間などを正しく定めることにより，労力と経費を節減できる。このためには，衛星資料の直接受信およびリアルタイム処理が必要であるが，一枚の画像処理に数時間かかっても，これは数日間の調査日数や労力の節減になる。また衛星データは船舶データを内挿，または外挿して海況の時空的分布をより正確に解釈するに用いられる。

衛星の漁業研究に対する今後の応用：例を挙げれば，資源評価に環境情報を組み合わせるときには衛星は膨大な海洋データを提供できる。また漁業と海洋汚染との関係の研究は衛星応用に期待される一つである。海に排出された汚染物資の拡散は水色その他の画像で観察できる。漁業資源の可能生産量を推定するための生態系エネルギー収支モデルの研究には衛星によるクロロフィルの測定が極めて重要である。

漁業者に対する情報サービスにおける衛星の応用：米国では衛星による海洋データを無線ファックス，無線電話，郵便，電話ファックスなどを用い漁業者に配布するいくつかのプロジェクトがある。衛星データを漁業情報に応用するための最初の動きは NASA と JPL（ジェット推進研究所）により推進された Seasat Commercial Demonstration Program で，これは海洋データの産出物を海洋ユーザーに提供する実用システムの開発をもたらした。

太平洋岸では AVHRR による温度前線の位置が漁場の探査のために商業漁業者や遊漁者に提供され，漁場探査の時間の節減に役立っている。

大西洋岸では GOES 衛星の高分解赤外画像と船舶資料による海況図が漁業者その他に提供されている。この海況図は多くの水産資源生物が住んでいる陸棚水の外縁を示すので漁業者の関心が高い。また，この図はロブスター漁業者にとっては

メキシコ湾流の暖水渦による強い流れのために生ずる漁具の損失を軽減するのに極めて有用である。また，前に述べたとおりメキシコ湾内の環状流（Loop Current）の流路を示す図が作られて漁業者に用いられている。

CZCSの青（第1バンド）と緑（第3バンド）との比を用いた水色前線図は，雲の状態にもよるが殆ど毎週1度の割りで太平洋側の漁業者に配布されている。太平洋岸を通過するNIMBUS-7，CZCSはスクリプス海洋学研究所で受信され，その翌日，研究所の無線局から漁船に放送されるほか，画像のカラー写真は速達郵便で漁港に送付される。これらの水色前線図やカラー写真はビンナガ，メカジキ，サケ等の商業漁業者や，南カリフォルニアの遊漁者が生産力の有望な漁場を求めるのに利用されている。

註：本報告は昭和60年6月に日本大学会館で行われた講演の内容に若干の補筆をしたものを著者から本紙に特別寄稿されたものである。

尚写真等は、送付が本号印刷に間に合わなかったので割愛した。

抄訳　　山中一郎